Biological Evaluation

For the Approval of Virginia’s Water Quality Standards Title 9 VACS 25-260 Water Quality Standards Regulations Adoption of Ammonia and Cadmium

Prepared by U.S. Environmental Protection Agency
for the U.S. National Marine Fisheries Service
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Contents

Executive Summary

This biological evaluation (BE) assesses the potential effects which may occur to federally listed threatened and endangered marine species and anadromous fish under the jurisdiction of the U.S. National Marine Fisheries Service (NMFS). The specific focus of this evaluation is the U.S. Environmental Protection Agency (EPA), Clean Water Act (CWA) approval of Virginia's proposed updates to its aquatic life criteria to be consistent with the EPA's recommended criteria for ammonia and cadmium. These criteria consider the best available science, including local and regional information, as well as applicable EPA policies, guidance, and legal requirements, to protect aquatic life including listed species. EPA finds that our proposed approval of Virginia's acute and chronic ammonia and cadmium criteria are Not Likely to Adversely Affect (NLAA) aquatic listed species through direct and indirect effects and will not adversely modify Atlantic sturgeon critical habitat.

EPA views the ammonia and cadmium criteria revisions as beneficial to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. The revisions are expected to aid in the conservation role of critical habitat. The listed sturgeon, turtles, and whales occurring in Virginia freshwaters and/or estuarine/marine waters are not sensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions.

Introduction

Endangered Species Act

Federally protected species are listed as endangered or threatened under the Endangered Species Act (ESA) of 1973, as amended, 16 U.S.C. section 1536, and its implementing regulations, 50 CFR Part 402. Section 7(a) of the ESA grants authority to impose requirements upon, federal agencies regarding endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that have been designated as critical ("critical habitat"). The ESA requires every federal agency, in consultation with the Secretary of the Interior, to ensure that any action it authorizes, funds, or carries out, in the United States or upon the high seas, is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat.

The United States Fish and Wildlife Service (FWS) administers Section 7 consultations for freshwater species, while NMFS administers Section 7 consultations for marine species and anadromous fish. This BE represents an effort by the EPA to informally consult with NMFS regarding the EPA approval action of Virginia WQS.

CWA Water Quality Standards Program

WQS defines the water quality goals for a waterbody by designating the use or uses of the water, by setting criteria necessary to protect the uses, and by preventing or limiting degradation of water quality through anti-degradation provisions. The CWA provides the statutory basis for the WQS program. Section 101(a)(2) of the CWA sets out a national goal that wherever attainable, waters achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable”).

Under Section 303(c) of the CWA and 40 CFR Part 131, states and authorized tribes (state) have the primary responsibility to develop and adopt WQS to protect their waters. Also under the CWA Section 303(c) and 40 CFR Part 131, the EPA is required to review and either approve or disapprove new and revised state WQS. New and revised state WQS are not considered effective for CWA purposes until approved by the EPA under CWA Section 303(c).

ESA Consultation for WQS

The EPA consults with the FWS and NMFS (Services) under Section 7 of ESA when approving certain changes to state WQS. The EPA must determine whether the proposed WQS may or may not affect listed species or their critical habitat. If the EPA determines that their action will have "no effect" on listed species or critical habitat, it is not required to consult with the Services. If the EPA determines that listed species and critical are not likely to be adversely affected, and the Service agrees with that determination, the Service provides concurrence in writing, and no further consultation is required. Finally, if the EPA determines that the WQS are likely to affect listed species adversely, it must initiate formal consultation with the Services.

Informal consultation includes a consultation in which the action agency determines that an action may affect, but is not likely to adversely affect listed species or critical habitat. An informal consultation generally involves the EPA developing a BE. To assist in evaluating the effect of approving a water quality criterion, the BE typically includes an evaluation of whether the presence of a pollutant at criterion magnitude, duration, and exceedance frequency is not likely to adversely affect any pertinent listed species or their critical habitat.

Description of the Proposed Federal Action

The federal action being evaluated under ESA, Section 7 is the approval by the EPA of the new and revised provisions regarding Virginia’s proposed updates to its cadmium and ammonia aquatic life water quality criteria. These criteria are adopted and implemented to maintain and protect the waters of Virginia, and they provide for the propagation and protection of aquatically-dependent listed species. The WQS revisions discussed below consider the best available science, including local and regional information, as well as the applicable EPA policies, guidance, and legal requirements, to protect aquatic life.

Purpose of the Proposed Federal Water Quality Criteria

Section 304(a) of the CWA authorizes the EPA to develop and revise recommended criteria for specific pollutants reflecting the latest scientific knowledge. These national recommended criteria do not themselves alter the applicable WQS of any state but serve as important scientific resources for states engaged in adopting new WQS or revising existing WQS. Water quality criteria adopted into state WQS could have the same numerical values as the national recommendation. However, states might want to adjust the water quality criteria developed under Section 304(a) to reflect local environmental conditions. Alternatively, states may use different data and assumptions than the EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses.

In 2013, the EPA published revised recommended criteria for ammonia and in 2016, the EPA published revised recommended criteria for cadmium, both of which are for the protection of aquatic life. The updated criteria are reflective of new toxicity data, which were unavailable during past updates. The criteria are intended to be protective of aquatic life, including federally listed species. Virginia proposed updates to its aquatic life ammonia and cadmium criteria to be consistent with the EPA's recommended criteria for ammonia and cadmium; therefore, the EPA's criteria documents are used throughout this BE to evaluate the potential effects of Virginia's WQS revisions on listed species (Ammonia, USEPA 2013; Cadmium, USEPA 2016). These criteria documents provide justification for water quality criteria, including comprehensive literature reviews and toxicological analyses.

Virginia's Ammonia and Cadmium Aquatic Life Criteria Revisions

On September 18, 2017, the Virginia Department of Environmental Quality (VADEQ) announced for public review and comment its proposed amendments to its cadmium and ammonia aquatic life water quality criteria. The comment period ended December 8, 2017. Virginia is expected to respond to public comments and publish revised cadmium and ammonia aquatic life water quality criteria within the coming year. Pursuant to the EPA's authority outlined in CWA Section 303(c) and 40 CFR Part 131, the EPA must review and approve the final new or revised cadmium and ammonia aquatic life water quality criteria. If the revisions to the aquatic life criteria are consistent with the revisions submitted to the EPA during the public comment period and evaluated below, the EPA requests concurrence from the Services to confirm that the revisions are not likely to adversely affect listed species or their critical habitat. If revisions to the aquatic life criteria significantly differ from what was published during the public comment period and evaluated below, the EPA will resubmit another BE for informal consultation.

Virginia's amendment to its cadmium criteria for the protection of fresh and saltwater aquatic life is based on the EPA's national recommended water quality criteria issued in 2016. The EPA updated national recommended cadmium criteria account for many new laboratory toxicity tests for cadmium. In addition, the effect of total hardness on cadmium toxicity was also revised using the newly acquired data, including toxicity data for 75 new species and 49 new genera.

Virginia has proposed to amend its freshwater ammonia aquatic life criteria to be consistent with the EPA's 2013 nationally recommended freshwater ammonia aquatic life criteria, issued by the EPA 2013. Like Virginia's current criteria, the proposed criteria are calculated as a function of temperature and pH and account for the presence or absence of trout and early life stages of fish. The recalculated ammonia criteria now incorporate toxicity data for freshwater mussels in the family unionidae, which are the most sensitive organisms in the recalculation data base. The new criteria are about twice as stringent as the existing criteria primarily because more recent toxicity data show that mussels and snails (including endangered species) are very sensitive to ammonia and the current ammonia criteria do not provide sufficient protection for these species. Site specific options to calculate criteria omitting mussel toxicity data are proposed to be used in waters where a demonstration has been made that mussels are absent; however, Virginia's consultation with FWS and the Virginia Department of Game and Inland Fisheries indicate freshwater mussels should be considered ubiquitous in Virginia and likely to be present in any perennial waterbody.

Action Area

The EPA's proposed approval of the Virginia revised ammonia and cadmium criteria applies to all waters of the United States (within the Commonwealth of Virginia) under federal jurisdiction. Jurisdiction over non-navigable, isolated, and intrastate waters would likely have to be determined on a case-by-case basis. The area evaluated for action is the surface waters of the Commonwealth. Waters of the Commonwealth are defined in section Title 62.1 of the Waters of the State, Ports and Harbors Law as "water includes all waters, on the surface and under the ground, wholly or partially within or bordering the Commonwealth or within its jurisdiction and which affect the public welfare."

According to ESA. the action area is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (50 CFR Part 402.02). This includes the project's footprint as well as the area beyond it that may experience direct or indirect effects that would not occur but for the action.

Listed Species and Critical Habitat within the Action Area

The EPA obtained a current list of species believed to or known to occur in Virginia from the NOAA Fisheries, Greater Atlantic Region website to determine if any listed, proposed or candidate species may be present in the action area. This list is included as an attachment to this BE.

1 Effects Assessment Methodologies

1.1 Acute Effect Assessment Methodology: Direct Effects to Freshwater Life Stages of Anadromous Species

The protectiveness of the freshwater acute ammonia and freshwater acute cadmium criteria magnitudes was assessed by identifying or estimating acute toxicity values (i.e., LC_{50}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Acute toxicity values used to develop the acute effects assessments were obtained from Appendix A of their respective 304(a) aquatic life criteria documents (Ammonia, USEPA 2013; Cadmium, USEPA 2016) and were specifically used to derive the acute criterion (i.e., bold values in Appendix A of USEPA 2013 and underlined values in USEPA 2016). These data were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Acute ammonia values have been normalized to a pH of 7 (all freshwater animals), consistent with criteria derivation (USEPA 2013). Acute cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$ consistent with criteria derivation (USEPA 2016). Ideally, species-specific toxicity data would be available for listed species of concern to support an acute effects assessment; however, data limitations often required use of surrogate toxicity data.

EPA considered acute toxicity data at the closest taxonomic level possible to calculate geometric mean acute toxicity values for each species assessed (i.e., LC_{50}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean acute toxicity values at the genus were calculated as the geometric mean of species-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. Species-specific and surrogate acute toxicity data obtained from Appendix A of USEPA (2013) and USEPA (2016) represent sensitivity expressed as a concentration that will acutely affect half of the species population. Acute toxicity data (expressed as LC_{50}) were transformed to an acute minimum effect threshold concentration (i.e., LC_5) which represents a concentration that is expected to affect 5% of the test population of a listed species under continuous exposure conditions, typically 48 to 96 hours depending on the species tested. Representing acute minimum effect thresholds as an LC_5 value is conservative because high-quality toxicity tests are considered acceptable even when up to 10% mortality is observed in the control treatment (organisms not exposed to the pollutant). Moreover, the use of a five percent toxicity value to represent an acute minimum effect threshold to an individual is consistent with reasonable and prudent measures (RPMs) outlined in a recent biological opinion (NOAA 2012).

Raw empirical acute toxicity data may be used to calculate LC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all acute tests provide concentration-response data. Therefore, species-specific, or surrogate LC_{50} values (which represent listed species 50% effect level), were transformed to an acute minimum effect threshold concentration through an acute taxonomic adjustment factor (TAF) or an acute mean adjustment factor (MAF). An acute TAF was calculated by averaging (geometric mean) the ratios of LC_{50}:LC_5 from chemical-specific acute toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus-, family-, and order-level acute TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean acute TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of an acute TAF within the same order as the species being assessed, EPA considered applying an acute invertebrate or vertebrate TAF (depending on whether the listed species assessed was an invertebrate or vertebrate). The acute invertebrate TAF and the acute vertebrate TAF were calculated as the geometric mean of genus-level LC_{50}:LC_5 ratios of invertebrates and vertebrates, respectively. An acute MAF was used to adjust species effect concentrations (i.e., LC_{50}) to low effect threshold concentrations (i.e., LC_5) when; 1) an acute TAF was not available within the same order as the listed species being assessed and 2) when the acute invertebrate TAF and the acute vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The acute MAF was calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios available. Acute invertebrate and vertebrate TAFs and the acute MAF were calculated as the geometric mean of their respective genus-level LC_{50}:LC_5 ratios to limit the influence of LC_{50}:LC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate LC_{50} values were then divided by an appropriate adjustment factor (i.e., acute TAF or acute MAF depending on data availability) to derive an acute minimum effect threshold concentration. Dividing LC_{50} values by an adjustment factor to identify a minimum-level effect concentration is an approach that is fundamentally similar to acute criteria derivation[1], but is more specific to the chemical and species assessed. Acute minimum effect threshold concentrations were then compared to corresponding criteria magnitudes (i.e., criterion maximum concentration [CMC]) to assess potential direct adverse effects of ammonia or cadmium exposures at the acute criterion concentration over conservative exposure durations.

The freshwater ammonia CMC is both pH- and temperature-dependent due to ammonia speciation differences. Vertebrate sensitivity to ammonia in freshwaters, however, is only dependent on pH, with tolerance decreasing as pH increases (see USEPA 2013). At any given temperature (e.g., 20°C), the freshwater ammonia CMC decreases with increasing pH. Figure 1-1 depicts the change in acute criterion magnitude with pH at a temperature of 20°C, and how the acute minimum effect threshold for Atlantic sturgeon (see Section 2.1.1) changes with the criterion magnitude proportionally (factor difference of 6.557 at 20°C). The acute effects assessment was developed using toxicity data normalized to reference conditions (pH = 7, temperature = 20°C) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity and the CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other surface waters.

[1]The Final Acute Value (FAV; fifth centile of genus mean acute values) is divided by 2.0 to derive the Criterion Maximum Concentration (CMC). The FAV was divided by 2.0 to ensure the CMC is representative of a concentration that will not severely adversely affect too many organisms. To support the development of the 1985 Guidelines, a Federal Register notice published in 1978 (Vol 43, pp. 21506-21518; USEPA 1978) outlined the derivation of a generic LC_{50} to LC_{low} (i.e., 0-10% effect) adjustment factor of 0.44 (or divide by 2.27). The adjustment factor of 2.27 was derived as the "*geometric mean of the quotients of the highest concentration that killed 0-10% of the organisms divided by the LC_{50} in 219 acute toxicity tests*." The geometric mean adjustment factor (2.27) outlined in the 1978 Federal Register notice was subsequently rounded to 2.0 in the 1985 Guidelines (Stephan et al. 1985).

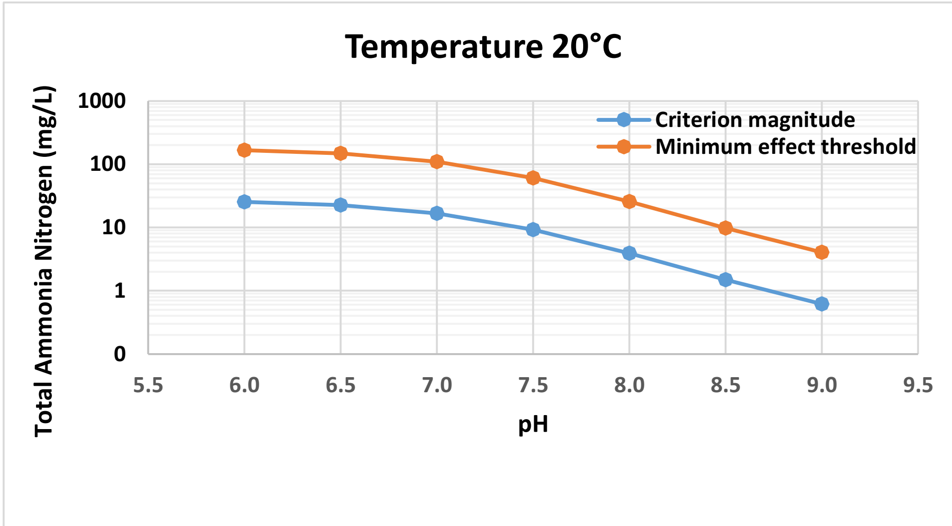

Figure 1-1. Acute ammonia criterion magnitudes extrapolated across a pH gradient at pH at a water temperature of 20°C. The acute minimum threshold concentration calculated for Atlantic sturgeon (see Section 2.1.1) is overlaid on the acute criterion magnitude. The freshwater acute ammonia criterion magnitude and the Atlantic sturgeon acute minimum effect threshold both decrease with increasing pH. The factor difference between the acute criterion magnitude and acute minimum effect threshold for Atlantic sturgeon is 6.557.

In contrast to ammonia, species sensitivity to cadmium in freshwaters is only dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The freshwater cadmium CMC increases with increasing hardness across the range of hardness in typical ambient surface water (acute toxicity hardness slope 0.9789). Figure 1-2 depicts the change in the cadmium CMC across water hardness of 25 to 400 mg/L as $CaCO_3$, and how the acute minimum effect threshold for Atlantic sturgeon (from Section 3.1.1) changes with the criterion magnitude proportionally (factor difference of 7.694). The acute freshwater cadmium effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CMC in those same reference conditions. Because species sensitivity to acute cadmium exposures in freshwater and the freshwater cadmium CMC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

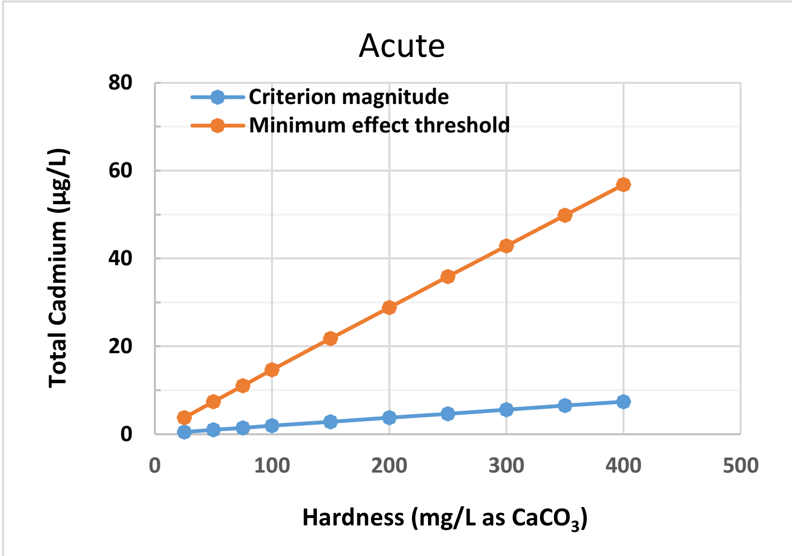

Figure 1-2. Acute cadmium criterion magnitudes extrapolated across a gradient of water hardness, overlaid with the Atlantic sturgeon acute minimum effect threshold concentration (see Section 3.1.1). The freshwater acute cadmium criterion magnitude and the Atlantic sturgeon acute minimum effect threshold both increase with increasing water hardness. The factor difference between the acute criterion magnitude and acute minimum effect threshold for Atlantic sturgeon is 7.694.

Assessing an acute criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the acute criterion magnitude indefinitely. If a listed species acute minimum effect threshold concentration is greater than the corresponding acute criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the acute criterion is Not Likely to Adversely Affect (NLAA) that particular listed species through direct acute effects in freshwaters.

1.2 Chronic Effect Assessment Methodology: Direct Effects to Freshwater Life Stages of Anadromous Species

The protectiveness of the chronic freshwater ammonia and chronic freshwater cadmium criteria magnitudes was assessed by identifying or estimating chronic toxicity values (i.e., EC_{20}) for Virginia aquatic listed species that were then adjusted to represent protective low effect threshold concentrations as described below. Ammonia chronic toxicity values used to develop the chronic effects assessments were obtained from Appendix B of the ammonia 304(a) aquatic life criteria document (USEPA 2013) and cadmium chronic toxicity data were obtained from Appendix C of the cadmium criteria document (USEPA 2016). These data were specifically used to derive the ammonia and cadmium criteria (i.e., bold values in Appendix B or underlined values in Appendix C, respectively) and were identified from EPA's ECOTOX database, the open and grey literature, and have been subjected to extensive data quality review (see Stephan et al. 1985 for data quality objectives). Chronic ammonia toxicity data (i.e., EC_{20}) used to support the effects assessment have been normalized to a pH of 7 (all freshwater species) and 20°C (freshwater invertebrates only), consistent with criteria derivation (USEPA 2013) and chronic cadmium toxicity data have been normalized to a total hardness of 100 mg/L as $CaCO_3$, consistent with criteria derivation (USEPA 2016).

Ideally, species-specific toxicity data would be available to support a chronic effects assessment; however, data limitations often required use of surrogate toxicity data. EPA considered chronic toxicity data at the closest taxonomic level to calculate geometric mean chronic toxicity values for each species assessed (i.e., EC_{20}). Considering surrogate toxicity data at the most phylogenetically-related taxonomic level possible accounts for genetically-derived traits conserved across taxa that may directly influence sensitivity to a pollutant. Geometric mean chronic toxicity values at the genus-, family-, and order-level were calculated as the geometric mean of lower taxonomic-level geometric mean values, since these mean values are meant to represent the sensitivity for a particular taxon. In certain cases, empirical chronic toxicity data were not available for surrogate species occurring within the same order as the listed species assessed. In these cases, appropriate acute data were transformed by an acute to chronic ratio (ACR) to estimate a chronic toxicity value (i.e., EC_{20}).

Unlike acute criteria derivation, which typically uses a generic LC_{50} to LC_{low} adjustment factor (i.e., 2.0[1]; Stephan et al. 1985), chronic criteria are based directly on chronic effect concentrations (e.g., EC_{20}) and do not incorporate a generic EC_x to EC_{low} adjustment factor. However, a concentration that results in chronic effects to 20% of a listed species population may not be considered acceptable for listed species. Therefore, a similar convention used for the acute assessment methodology was applied to the chronic effects assessment methodology to determine a chronic minimum effect threshold concentration (i.e., EC_5) from chronic toxicity values.

Raw empirical chronic toxicity data may be used to calculate EC_5 values directly from the concentration-response (C-R) curves of the listed species-specific toxicity tests, when available. However, not all chronic tests provide concentration-response data. Therefore, species-specific, or surrogate EC_{20} values (which represent listed species 20% effect level), were transformed to a chronic minimum effect threshold concentration through the use of a chronic taxonomic adjustment factor (TAF) or a chronic mean adjustment factor (MAF), in the same manner as the acute adjustment factors described previously. Specifically, a chronic TAF was calculated by averaging (geometric mean) the ratios of EC_{20}:EC_5 from chemical specific chronic toxicity tests conducted using species in the closest possible phylogenetic proximity (same species, genus, family, or order) as the listed species that is being assessed (genus-, family-, and order-level chronic TAFs were calculated as the geometric mean of lower taxonomic-level geometric mean chronic TAFs to ensure adequate representation of all lower-level taxa for a particular taxon). When data availability did not allow for the development of a chronic TAF within the same order as the species being assessed, EPA considered applying a chronic invertebrate or vertebrate TAF (depending on whether the species assessed was an invertebrate or vertebrate). The chronic invertebrate TAF and the chronic vertebrate TAF were calculated as the geometric mean of genus-level EC_{20}:EC_5 ratios of invertebrates and vertebrates, respectively. A chronic MAF was used to adjust species effect concentrations (i.e., EC_{20}) to low effect threshold concentrations (i.e., EC_5) when; 1) a chronic TAF was not available within the same order as the listed species being assessed and 2) when the chronic invertebrate TAF and the chronic vertebrate TAF were not significantly different via a two-sample t-test assuming unequal variances ($\alpha = 0.05$). The chronic MAF was calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios available. Chronic invertebrate and vertebrate TAFs and the chronic MAF were calculated as the geometric mean of their respective genus-level EC_{20}:EC_5 ratios to limit the influence of EC_{20}:EC_5 ratios from species that are overly represented in a dataset, similar to criteria derivation (Stephan et al. 1985).

Listed species-specific or surrogate EC_{20} values were then divided by an appropriate adjustment factor (i.e., chronic TAF or chronic MAF depending on data availability) to derive a chronic minimum effect threshold concentration. Chronic minimum effect threshold concentrations were then compared to the corresponding criterion magnitude (i.e., criterion continuous concentration [CCC]) to assess potential adverse effects of ammonia or cadmium exposures at the chronic criterion concentration.

The freshwater ammonia CCC is pH- and temperature-dependent. Vertebrate sensitivity to ammonia in freshwaters, however, is only dependent on pH, with tolerance decreasing as pH increases (see USEPA 2013). At any given temperature (e.g., 20°C), the freshwater ammonia CCC decreases with increasing pH. Figure 1-3 depicts the change in the ammonia CCC across waters with different pH and how the chronic minimum effect threshold for Atlantic sturgeon (see Section 2.1.2) changes proportionally with the criterion magnitude (factor difference of 6.555). Because species sensitivity and the CCC both change similarly, conclusions based on reference conditions translate to other surface waters.

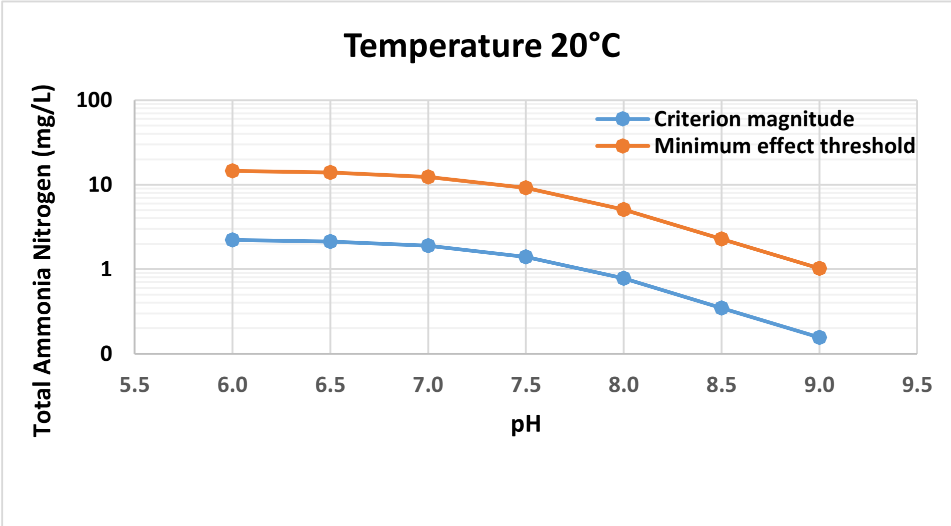

Figure 1-3. Chronic ammonia criterion magnitude extrapolated across a pH gradient (at a water temperature of 20°C) with the Atlantic sturgeon (see Section 2.1.2) chronic ammonia minimum effect threshold concentration overlaid. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for Atlantic sturgeon is 6.555.

In contrast to ammonia, species sensitivity to cadmium in freshwater is dependent on water hardness, with tolerance increasing as hardness increases (see USEPA 2016). The cadmium CCC increases with increasing hardness across the range of hardness typical of natural ambient surface water, but with a slightly shallower slope than for the CMC (chronic toxicity hardness slope 0.7977). Figure 1-4 depicts the change in the cadmium CCC across water hardness and how the Atlantic sturgeon chronic minimum effect threshold (see Section 3.1.2) changes with the chronic freshwater cadmium criterion magnitude proportionally (factor difference of 3.432). The chronic effects assessment was developed using toxicity data normalized to a reference condition (hardness = 100 mg/L) and compared to the corresponding CCC in those same reference conditions. Because species sensitivity and the CCC both change similarly across water chemistries, conclusions based on reference conditions translate to other water chemistries.

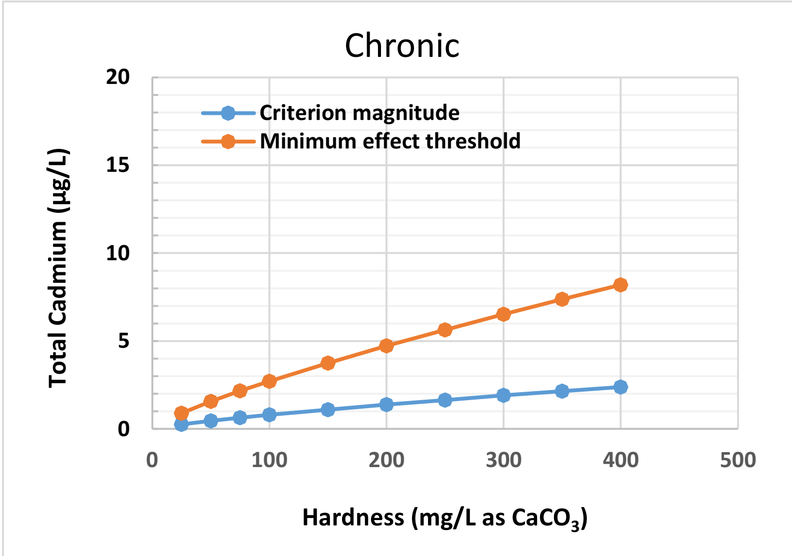

Figure 1-4. Chronic cadmium criterion magnitudes extrapolated across a gradient of water hardness overlaid with the Atlantic sturgeon chronic minimum effect threshold concentration (see Section 3.1.2). The criterion magnitude increases and the Atlantic sturgeon chronic minimum effect threshold both increase with increasing water hardness. The factor difference between the chronic criterion magnitude and chronic minimum effect threshold for Atlantic sturgeon is 3.432.

Assessing a chronic criterion magnitude alone does not consider the duration and frequency components of the criterion and represents an overly conservative exposure scenario that assumes a pollutant concentration in all Virginia freshwaters will be at the chronic criterion magnitude indefinitely. If a listed species chronic minimum effect threshold concentration is greater than the corresponding chronic criterion magnitude, then a refined assessment and consideration of the criterion duration and realistic exposure is not necessary, and approval of the chronic criterion is Not Likely to Adversely Affect (NLAA) that particular listed species through direct chronic effects in freshwaters.

1.3 Acute and Chronic Effect Assessment Methodology: Direct Effects to Estuarine/Marine Species and Saltwater Life Stages of Anadromous Species

In additional to the freshwater cadmium criterion, Virginia has also proposed to adopt the acute and chronic cadmium criterion for estuarine/marine waters (USEPA 2016). Given relative data limitations associated with saltwater toxicity data, the acute and chronic estuarine/marine cadmium criteria were assessed together in a qualitative approach by considering limited exposure potential and previous biological opinions.

Virginia has not proposed to adopt or update estuarine/marine ammonia criteria. Freshwater and terrestrial species with range or critical habitat in Virginia waters are subject to consultation with U.S. Fish and Wildlife Service.

1.4 Indirect Effects: Assessment of Acute and Chronic Criteria

Following assessment of direct acute and chronic effects, EPA considered and assessed potential indirect effects of the water quality standard approval actions on anadromous and estuarine/marine species. To assess potential indirect effects, EPA considered conservatisms associated with criteria derivation and implementation as well as potential effects to listed animal prey items.

1.5 Listed Species: Final Effects Determinations

Final effect determinations were based on direct and/or indirect effects of EPA's approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) water quality standards in Virginia. EPA considered direct acute and chronic effects as well as indirect effects to make a final effects determination.

1.6 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

Following listed species final effects determinations, EPA assessed designated critical habitats pertaining to anadromous and estuarine/marine species with critical habitats overlapping the action area. EPA considered Physical and Biological Features (PBFs, formally Primary Constituent Elements [PCEs]) essential to critical habitat and potential effects to listed species prey items (evaluated through the indirect effects assessment) to determine if the proposed action is *Likely to Adversely Modify* critical habitat or if the proposed action is *Not Likely to Adversely Modify* critical habitat.

2 Ammonia Effects Assessment

2.1 Sturgeon: Shortnose (*Acipenser brevirostrum*) and Atlantic (*Acipenser oxyrinchus oxyrinchus*)

2.1.1 Sturgeon Acute Ammonia Effects Assessment: Freshwater

2.1.1.1 Identifying Sturgeon Acute Ammonia Data

High-quality species-level acute data (i.e., bold values in Appendix A of the 2013 freshwater ammonia 304(a) aquatic life criteria document) were not available for the Atlantic sturgeon. Therefore, the species-level acute toxicity data for shortnose sturgeon were applied as a genus-level surrogate toxicity value for the Atlantic sturgeon. The shortnose sturgeon Species Mean Acute Value (SMAV) is composed of a single, definitive LC_{50} value (156.7 mg/L, normalized to pH 7) from a test with a sensitive life stage (Fontenot et al. 1998) and represents the *Acipenser* Genus Mean Acute Value (GMAV) applicable to the Atlantic sturgeon species (Table 2-1).

Table 2-1. Data used to calculate the SMAV and GMAV representative of shortnose and Atlantic sturgeon acute sensitivity to ammonia.

Order	Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	156.7	156.7
Acipenseriformes	Acipenseridae	Atlantic sturgeon,	N/A	

		Acipenser oxyrinchus oxyrinchus		

[a] Normalized to pH 7 (USEPA 2013).
N/A: not available

2.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

The published acute toxicity study (Fontenot et al. 1998) used to calculate the shortnose sturgeon SMAV and the *Acipenser* GMAV (which is representative of Atlantic sturgeon) did not contain or report raw toxicity data. Because no raw acute toxicity data are available for fish species in the same order, no acute order-level TAF could not? be calculated. As a result, EPA obtained and analyzed raw concentration-response (C-R) data for all tests used to derive the acute criterion (bold values in Appendix A of USEPA [2013]) where such data were reported or could be obtained to inform the derivation of a vertebrate-level TAF and a MAF, if necessary (i.e., if the vertebrate and invertebrate-level acute TAFs differ from one another).

Raw acute toxicity data were fit to C-R models using EPA's Toxicity Relationship Analysis Program (TRAP, version 1.3a) to calculate LC_{50} and corresponding LC_5 values for 83 tests representing 34 species (18 invertebrates and 16 vertebrates). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain LC_{50}:LC_5 ratios, 44 ratios remained resulting in nine genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.157 mg/L, variance = 0.4447 mg/L) and 11 genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 1.440 mg/L, variance = 0.0491 mg/L). Analysis of the two arithmetic means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are different *(t stat [3.088] > t critical for two tail [2.262]*). Therefore, an acute vertebrate TAF is more appropriate than an acute MAF to transform the *Acipenser* GMAV applicable to the shortnose and Atlantic sturgeon (156.7 mg/L) to an acute minimum effect threshold concentration.

Table 2-2 provides the 11 genus-level LC_{50}:LC_5 ratios used to derive the acute vertebrate TAF. Individual test ratios ranged from 1.034 to 1.925. The acute vertebrate TAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 1.426 (n = 11; see Appendix A.1 for raw toxicity test data, TRAP models and outputs for the 17 acute ammonia toxicity tests used to derive the acute vertebrate TAF; Appendix A.2 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain ammonia C-R models).

Table 2-2. Acute LC_{50}:LC_5 ratios from analysis of 17 high-quality acute ammonia toxicity tests with freshwater aquatic vertebrates used to derive an acute vertebrate adjustment factor (acute vertebrate TAF) for the shortnose and Atlantic sturgeon.
(Note: the acute vertebrate TAF is the geometric mean of all available genus-level LC_{50}:LC_5 ratios for vertebrates)**.**

Order	Family	Species	LC_{50} (mg/L)	LC_{05} (mg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Salmoniformes	Salmonidae	Rainbow trout (40.0 g; resting fish), *Oncorhynchus mykiss*	202.2	105.1	1.925	Am-Acute-56	Wicks et al. 2002	1.925	1.925
Cypriniformes	Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	21.14	15.04	1.406	Am-Acute-58	Hazel et al. 1979	1.387	1.387
Cypriniformes	Cyprinidae	Rainbow dace, *Cyprinella lutrensis*	7.040	5.144	1.369	Am-Acute-59	Hazel et al. 1979		
Cypriniformes	Cyprinidae	Common carp (299 mg), *Cyprinus carpio*	51.65	40.37	1.279	Am-Acute-62	Hasan and MacIntosh 1986	1.279	1.279
Cypriniformes	Cyprinidae	Rio Grande silvery minnow (3-5 d old), *Hybognathus amarus*	17.52	12.52	1.399	Am-Acute-63	Buhl 2002	1.399	1.399
Cypriniformes	Cyprinidae	Fathead minnow (0.2 g), *Pimephales promelas*	43.46	42.03	1.034	Am-Acute-69	Swigert and Spacie 1983	1.188	1.188
Cypriniformes	Cyprinidae	Fathead minnow (0.5 g), *Pimephales promelas*	42.76	31.33	1.365	Am-Acute-70	Swigert and Spacie 1983		
Cypriniformes	Catostomidae	White sucker (92 mm, 6.3 g), *Catostomus commersonii*	29.27	20.35	1.439	Am-Acute-71	Reinbold and Pescitelli 1982c	1.439	1.439
Siluriformes	Ictaluridae	Channel catfish, *Ictalurus punctatus*	32.17	21.66	1.485	Am-Acute-74	Reinbold and Pescitelli 1982d	1.485	1.485
Perciformes	Centrarchidae	Pumpkinseed (4.13-9.22 g), *Lepomis gibbosus*	10.60	6.504	1.629	Am-Acute-77	Jude 1973	1.629	1.425
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	6.752	5.940	1.137	Am-Acute-80	Hazel et al. 1979	1.247	
Perciformes	Centrarchidae	Bluegill (0.9 g), *Lepomis macrochirus*	57.29	46.32	1.237	Am-Acute-83	Swigert and Spacie 1983		
Perciformes	Centrarchidae	Bluegill (1.2 g), *Lepomis macrochirus*	37.54	27.22	1.379	Am-Acute-84	Swigert and Spacie 1983		
Perciformes	Percidae	Orangethroat darter, *Etheostoma spectabile*	35.15	19.97	1.760	Am-Acute-85	Hazel et al. 1979	1.620	1.620
Perciformes	Percidae	Orangethroat darter, *Etheostoma spectabile*	8.151	5.465	1.491	Am-Acute-86	Hazel et al. 1979		
Perciformes	Cichlidae	Mozambique tilapia (juvenile), *Oreochromis mossambicus*	118.2	106.2	1.113	Am-Acute-87	Rani et al. 1998	1.113	1.113
Anura	Hylidae	Pacific tree frog (embryo), *Pseudacris regilla*	62.51	39.45	1.584	Am-Acute-89	Schuytema and Nebeker 1999a	1.584	1.584

2.1.1.3 Calculating Sturgeon Acute Ammonia Minimum Effect Threshold

Dividing the shortnose sturgeon LC_{50} value (156.7 mg/L; genus-level surrogate value for Atlantic sturgeon) by the acute vertebrate TAF (1.426) results in an acute ammonia minimum effect threshold concentration of 109.9 mg/L (normalized to pH 7) for both sturgeon species.

2.1.1.4 Sturgeon: Acute Ammonia Effects Determination

The acute ammonia CMC at pH 7 (17 mg/L), is approximately 6.5 times lower than the sturgeon acute ammonia minimum effect threshold of 109.9 mg/L. The sturgeon acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the freshwater acute ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the shortnose and Atlantic sturgeons through direct acute effects.

2.1.2 Sturgeon Chronic Ammonia Effects Assessment: Freshwater

2.1.2.1 Identifying Sturgeon Chronic Ammonia Data

High-quality empirical chronic toxicity data within the Order Acipenseriformes are not available to serve as chronic toxicity data representative of the shortnose and Atlantic sturgeon. As a result, the shortnose sturgeon SMAV (which also represents the *Acipenser* GMAV applicable to Atlantic sturgeon) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 17.46 mg/L (Table 2-3). This representative chronic value for the two sturgeon species was calculated by dividing the acute toxicity value for shortnose sturgeon (156.7 mg/L; surrogate value for Atlantic sturgeon) by the reported vertebrate ammonia acute:chronic ratio (Vert-ACR; USEPA 2013). The Vert-ACR (8.973) is based on ACRs representing five families of freshwater fishes which range from 4.8 to 14.75 (Appendix F of USEPA 2013).

Table 2-3. Data used to calculate the chronic toxicity values (i.e., EC_{20}) representative of sturgeon chronic sensitivity to ammonia.

Order	Family	Species	SMAV (mg/L)[a]	GMAV (mg/L)[a]	VERT-ACR	GMCV (mg/L)[a]
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	156.7	156.7	8.973	17.46
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A			

[a] Normalized to pH 7 (USEPA 2013).
N/A: not available

2.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the shortnose and Atlantic sturgeon or species within the Order Acipenseriformes, and therefore, no raw toxicity data are available to support the derivation of a sturgeon-specific EC_{20}:EC_5 adjustment factor at or below the order-level. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the chronic criterion (USEPA 2013 Appendix B bold values) where such data were reported or could be obtained to derive a chronic vertebrate-level TAF and a MAF, if necessary (i.e., if the vertebrate and invertebrate-level chronic TAFs differ from one another).

Raw chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 31 tests representing 20 species (10 invertebrate and 10 fish species). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios for use in calculating a chronic MAF, 20 ratios remained resulting in five genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.341 mg/L, variance = 0.01208 mg/L) and seven genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.472 mg/L, variance = 0.01326 mg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same *(t stat [-2.004] < t critical for two tail [2.262]*). As a result, the chronic MAF was used to transform the GMCV applicable to the shortnose and Atlantic sturgeon (17.46 mg/L) to a chronic minimum effect threshold concentration.

Table 2-4 provides the 12 genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.183 to 1.881 (Table 2-4). The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.412 (see Appendix A.3 for raw toxicity test data, TRAP models and outputs for the 20 chronic ammonia toxicity tests used to derive the chronic MAF; Appendix A.4 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain ammonia toxicity tests).

Table 2-4. Chronic EC_{20}:EC_5 ratios from analysis of 20 high-quality chronic ammonia toxicity tests with freshwater aquatic organisms used to derive a chronic ammonia MAF representative of the shortnose and Atlantic sturgeon.
(Note: the chronic MAF is the geometric mean of all available genus-level EC_{20}:EC_5 ratios).

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Veneroida	Pisidiidae	Long fingernailclam, *Musculium transversum*	6.049	4.626	1.308	Am-Chronic-4	Anderson et al. 1978	1.308	1.308
Neotaenioglossa	Hydrobiidae	Pebblesnail (1.81 mm juvenile), *Fluminicola* sp.	2.269	1.559	1.455	Am-Chronic-6	Besser 2011	1.455	1.455
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia acanthina*	49.59	41.21	1.203	Am-Chronic-7	Mount 1982	1.203	1.322
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	15.57	10.36	1.503	Am-Chronic-8	Nimmo et al. 1989	1.453	
Diplostraca	Daphniidae	Water flea, *Ceriodaphnia dubia*	5.720	4.072	1.405	Am-Chronic-9	Willingham 1987		
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	8.265	5.026	1.645	Am-Chronic-10	Gersich et al. 1985	1.436	1.436
Diplostraca	Daphniidae	Water flea, *Daphnia magna*	20.86	16.64	1.254	Am-Chronic-11	Reinbold and Pescitelli 1982a		
Plecoptera	Pteronarcyidae	Stonefly, *Pteronarcella badia*	133.8	113.0	1.183	Am-Chronic-13	Thurston et al. 1984b	1.183	1.183
Salmoniformes	Salmonidae	Lahontan cutthroat trout (fertilized), *Oncorhynchus clarkii henshawi*	19.32	10.83	1.784	Am-Chronic-15	Koch et al. 1980	1.784	1.497
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	8.982	7.148	1.257	Am-Chronic-16	Brinkman et al. 2009	1.257	
Esociformes	Esocidae	Northern pike (fertilized), *Esox lucius*	14.81	10.91	1.357	Am-Chronic-17	Harrahy et al. 2004	1.357	1.357
Cypriniformes	Cyprinidae	Common carp (fertilized), *Cyprinus carpio*	8.246	5.612	1.469	Am-Chronic-18	Mallet and Sims 1994	1.469	1.469
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	4.656	3.361	1.385	Am-Chronic-19	Mayes et al. 1986	1.565	1.565
Cypriniformes	Cyprinidae	Fathead minnow (embryo-larvae), *Pimephales promelas*	7.396	5.561	1.330	Am-Chronic-20	Adelman et al. 2009		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	5.795	3.081	1.881	Am-Chronic-21	Swigert and Spacie 1983		
Cypriniformes	Cyprinidae	Fathead minnow, *Pimephales promelas*	1.903	1.099	1.732	Am-Chronic-22	Thurston et al. 1986		
Cypriniformes	Catostomidae	White sucker (3 d old embryo), *Catostomus commersonii*	1.296	0.783	1.656	Am-Chronic-23	Reinbold and Pescitelli 1982a	1.656	1.656
Perciformes	Centrarchidae	Bluegill, *Lepomis macrochirus*	1.855	1.402	1.323	Am-Chronic-27	Smith et al. 1984	1.323	1.323

Order	Family	Species	EC_{20} (mg/L)	EC_{05} (mg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	8.395	5.585	1.503	Am-Chronic-30	Broderius et al. 1985	1.440	1.440
Perciformes	Centrarchidae	Smallmouth bass, *Micropterus dolomieu*	1.610	1.168	1.379	Am-Chronic-31	Broderius et al. 1985		

2.1.2.3 Calculating Sturgeon Chronic Ammonia Minimum Effect Threshold

Dividing the estimated sturgeon EC_{20} value (17.46 mg/L) by the chronic MAF (1.412) results in a chronic minimum effect threshold concentration of 12.37 mg/L (normalized to pH 7).

2.1.2.4 Sturgeon: Chronic Ammonia Effects Determination

The chronic ammonia CCC at pH 7 (1.9 mg/L), is 6.5 times lower than the Atlantic and shortnose sturgeons chronic minimum effect threshold concentration of 12.37 mg/L. The sturgeon chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the chronic freshwater ammonia water quality standard is Not Likely to Adversely Affect (NLAA) the shortnose and Atlantic sturgeons through direct chronic effects.

2.1.3 Sturgeon Ammonia Indirect Effects Assessment: Freshwater

Aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute ammonia criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic ammonia criterion typically assume receiving streams are continually at 30Q10 or 30Q5 low-flow conditions (i.e., 30-day average lowest flow over the course of a 5 or 10-year period). As a result, excess dilution limits instream ammonia concentrations and drastically decreases the probability *in situ* ammonia concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also layer on an additional level of conservatism by ensuring facilities discharge ammonia at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99^{th} centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99^{th} centile of an effluent distribution ensures a 99% chance facilitates discharge ammonia at concentrations less than those that would cause receiving stream ammonia concentrations to reach criteria magnitudes under critical flow conditions (which are independent and also exceedingly rare events; USEPA 1991). Additionally, even if *in situ* exposures were to match the acute or chronic criteria magnitudes, the broad aquatic community, including sturgeon prey items, will be adequately protected because aquatic life criteria are based on the fifth centile of sensitive genera.

Shortnose and Atlantic sturgeon broadly rely on benthic invertebrates, including mussels, crustaceans, and insects as primary food sources. Freshwater unionid mussels are among the most sensitive genera to acute and chronic ammonia exposures, with aquatic insects and

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[2] A Waste Load Allocation (WLA) is the maximum allowable pollutant concentration in an effluent from a discharger that, after accounting for available dilution under critical low flow conditions (e.g., 1Q10, 30Q5, 30Q10), will meet an applicable water quality criterion (USEPA 1991).

crustaceans being relatively insensitive (USEPA 2013). The acute and chronic ammonia criteria are both primarily driven by mussel sensitivity. If ammonia concentrations in Virginia freshwater ecosystems were to occur at acute or chronic criteria magnitudes and durations (which is highly unlikely based the conservative implementation of criteria in NPDES permit limits), a small portion of individuals in the most sensitive mussel populations may experience short-term effects. Further, if ammonia were to exist at criteria concentrations indefinitely in Virginia freshwaters (which is not the intent of the action considering the full definition of criteria include magnitude, duration, and frequency), shortnose sturgeon and Atlantic sturgeon would not be indirectly affected because only a small portion of mussels would experience effects and sturgeon do not rely exclusively on mussels as a food source, with additional sturgeon food sources (e.g., insects and benthic worms) remaining tolerant to acute and chronic ammonia exposures (USEPA 2013). As a result, EPA approval of Virginia freshwater acute and chronic ammonia standards is Not Likely to Adversely Affect (NLAA) shortnose and Atlantic sturgeon through indirect effects.

3 Cadmium Effects Assessment

3.1 Sturgeon: Shortnose (*Acipenser brevirostrum*) and Atlantic (*Acipenser oxyrinchus oxyrinchus*)

3.1.1 Sturgeon Acute Cadmium Effects Assessment: Freshwater

3.1.1.1 Identifying Sturgeon Acute Cadmium Data

High quality species-level acute data were not available for either sturgeon species. Therefore, genus-level acute toxicity data are used to represent the sensitivity of shortnose and Atlantic sturgeons to acute cadmium exposures. The GMAV is based on a single SMAV for the white sturgeon (Table 3-1). The SMAV is composed of a single, non-definitive LC_{50} value (<33.78 µg/L, normalized to a total hardness of 100 mg/L as $CaCO_3$) from a test with a sensitive life stage (Calfee et al. 2014). The non-definitive LC_{50} value introduces uncertainty in the GMAV estimate and it is reasonable to consider how much lower a definitive LC_{50} value would be compared to the non-definitive LC_{50} estimate. EPA was able to independently evaluate the C-R curve used to calculate the white sturgeon-based GMAV (which is representative of shortnose and Atlantic sturgeon) from Calfee et al. (2014). Acute toxicity data were provided in Table A-2 of the parent USGS report (Ingersoll and Mebane 2014), which provided sufficient supplemental information to create the C-R curve for the test (see Cd-Acute-93 in Appendix B.2). The TRAP model generated from the data is unacceptable for deriving an LC_{50} to LC_5 ratio due to no effect within the area of concern, especially at low-levels (i.e., 5%), but provides a definitive LC_{50} value of 23.14 total cadmium (normalized to a hardness of 100 mg/L). The LC_{50} value calculated from Ingersoll and Mebane (2014; see Cd-Acute-93 in Appendix B.2) contains some underlying uncertainty because the lowest test concentrations (beside the negative control group) resulted in 70% mortality.

Nevertheless, use of the definitive LC_{50} (23.14 total cadmium, normalized to a hardness of 100 mg/L) for white sturgeon as the *Acipenser* GMAV may be appropriate for several reasons. First, Calfee et al. (2014) tested six different sturgeon life stages ranging from 2 to 89 days post hatch (dph) and reported normalized (hardness = 100 mg/L) LC_{50} values ranging from >11.65 to >355.0 µg total Cd/L. Of the six life stages tested, EPA concluded white sturgeon tested at 61 dph were the most sensitive to acute cadmium toxicity, and the non-definitive LC_{50} value (reported by Calfee et al. [2014] as <33.78 µg/L; hardness = 100 mg/L; total cadmium) for white sturgeon of this age was among the most sensitive of LC_{50} values available for sturgeon. Second, Calfee et al. (2014) comparatively assessed sturgeon and rainbow trout sensitivities to cadmium and concluded, "*Rainbow trout were more sensitive to cadmium exposure than white sturgeon for all life stages tested.*" Calfee et al. (2014) further states, "*Rainbow trout in the present study were especially sensitive to cadmium relative to other species*," which is consistent with salmonid genera ranking among the most sensitive in the species sensitivity distribution (SSD) used to derive the acute cadmium criterion (USEPA 2016). The acute cadmium criterion is based on the fifth centile of sensitive genera and is largely influenced by salmonid sensitivity. Because Calfee et al. (2014) determined salmonids are more sensitive to cadmium than sturgeon, and the acute criterion is based on salmonid sensitivity, the acute criterion is expected to be protective of sturgeon and the use of a definitive acute toxicity estimate that contains some underlying uncertainty given the lack of low-level effects in the C-R curve (see Cd-Acute-93 in Appendix B.2) will not result in spurious conclusions.

Table 3-1. Data used to calculate the *Acipenser* GMAV representative of shortnose and Atlantic sturgeon acute sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]
Acipenseriformes	Acipenseridae	White sturgeon, *Acipenser transmontanus*	23.24	23.14
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	N/A	
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A	

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available

3.1.1.2 Deriving LC_{50} to LC_5 Acute Adjustment Factor

As previously described, the TRAP model (see Cd-Acute-93 in Appendix B.2) produced by analysis of the data from the acute toxicity test with 61 dph white sturgeon (Calfee et al. 2014) is unacceptable for use as a *Acipenser*-specific (genus-level) taxonomic adjustment factor because of a lack of low-level effects resulting in no responses in the area of interest along the C-R curves (i.e., 5% - 50%). No other acute toxicity tests with C-R data are available for the Order Acipenseriformes. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the acute cadmium criterion (underlined values in Appendix A of USEPA 2016; Table 3-2) where such data were reported or could be obtained to derive an acute vertebrate TAF or acute MAF, if necessary (i.e., if the vertebrate and invertebrate-level acute TAFs differ from one another).

Raw acute toxicity data were fit to C-R models using EPA's TRAP software to calculate LC_{50} and corresponding LC_5 values for 69 tests representing 28 species (18 invertebrate and 10 vertebrates, including an amphibian). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of these unacceptable or uncertain LC_{50}:LC_5 ratios for use in calculating an acute MAF, 35 ratios remained resulting in seven genus-level LC_{50}:LC_5 ratios for invertebrate species (arithmetic mean = 2.857 µg/L, variance = 2.186 µg/L) and six genus-level LC_{50}:LC_5 ratios for vertebrate species (arithmetic mean = 2.106 µg/L, variance = 0.2589 µg/L). Analysis of the two arithmetic means via a two sample t-test assuming unequal variances ($\alpha = 0.05$) indicated the means are the same *(t stat [1.259] < t critical for two tail [2.306]*). As a result, the acute MAF was used to transform the *Acipenser* GMAV representative of shortnose and Atlantic sturgeon (<33.78 µg/L) to an acute minimum effect threshold concentration.

Table 3-2 provides the 13 genus-level LC_{50}:LC_5 ratios used to derive the cadmium acute MAF. The acute MAF calculated as the geometric mean of all genus-level LC_{50}:LC_5 ratios is 2.310 (see Appendix B.3 for raw toxicity test data, TRAP models and outputs for the 35 acute cadmium toxicity tests used to derive the acute MAF; Appendix B.4 includes the raw toxicity data, TRAP models and output for all unacceptable and uncertain cadmium toxicity tests).

Table 3-2. Acute LC_{50}:LC_5 ratios from analysis of 35 high-quality acute cadmium toxicity tests with freshwater aquatic organisms used to derive an acute mean adjustment factor (MAF) for the shortnose and Atlantic sturgeons.

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	56,141	27,732	2.024	Cd-Acute-2	Rathore and Khangarot 2002	2.278	2.278
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	26,650	10,289	2.590	Cd-Acute-5	Rathore and Khangarot 2002		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	423.3	299.5	1.414	Cd-Acute-6	Rathore and Khangarot 2003		
Tubificida	Naididae	Tubificid worm, *Tubifex tubifex*	6,463	1,778	3.634	Cd-Acute-8	Rathore and Khangarot 2003		
Basommatophora	Lymnaeidae	Pond snail (juvenile, stage II, 9 wk), *Lymnaea stagnalis*	1,735	718.0	2.416	Cd-Acute-9	Coeurdassier et al. 2004	2.016	2.016
Basommatophora	Lymnaeidae	Pond snail (adult, 20 wk), *Lymnaea stagnalis*	1,670	1,051	1.590	Cd-Acute-10	Coeurdassier et al. 2004		
Basommatophora	Lymnaeidae	Pond snail (juvenile, 25 mm), *Lymnaea stagnalis*	350.8	164.3	2.135	Cd-Acute-12	Pais 2012		
Basommatophora	Physidae	Snail (adult, 3.3-15 mm), *Physa acuta*	1,619	1,375	1.177	Cd-Acute-14	Woodard 2005	1.177	1.177
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Ceriodaphnia dubia*	30.54	13.76	2.220	Cd-Acute-17	Shaw et al. 2006	2.220	2.220
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	170.8	13.67	12.49	Cd-Acute-19	Shaw et al. 2006	4.580	4.580
Diplostraca	Daphniidae	Cladoceran (<24 hr), *Daphnia magna*	517.6	308.3	1.679	Cd-Acute-22	Perez and Beiras 2010		
Decapoda	Cambaridae	Crayfish (adult), *Orconectes virilis*	6,007	2,427	2.475	Cd-Acute-30	Mirenda 1986	2.475	2.475
Ephemeroptera	Heptageniidae	Mayfly (nymph), *Rhithrogena hageni*	10,924	2,080	5.251	Cd-Acute-35	Brinkman and Vieira 2007; Brinkman and Johnston 2008	5.251	5.251
Salmoniformes	Salmonidae	Rainbow trout (8.8 g), *Oncorhynchus mykiss*	3.055	1.759	1.737	Cd-Acute-47	Phipps and Holcombe 1985	2.067	2.067
Salmoniformes	Salmonidae	Rainbow trout	1.682	0.5849	2.876	Cd-Acute-48	Stubblefield 1990		

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
		(juvenile, 18.3 g), *Oncorhynchus mykiss*							
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	2.679	1.683	1.591	Cd-Acute-49	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (36 g), *Oncorhynchus mykiss*	7.052	3.007	2.345	Cd-Acute-53	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.773	1.726	1.606	Cd-Acute-55	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 1.0 g), *Oncorhynchus mykiss*	2.152	1.116	1.928	Cd-Acute-58	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (fry, 2.5 g), *Oncorhynchus mykiss*	10.14	5.298	1.914	Cd-Acute-60	Davies and Brinkman 1994b		
Salmoniformes	Salmonidae	Rainbow trout (263 mg), *Oncorhynchus mykiss*	0.6500	0.3493	1.861	Cd-Acute-61	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (659 mg), *Oncorhynchus mykiss*	0.4134	0.2108	1.961	Cd-Acute-62	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,150 mg), *Oncorhynchus mykiss*	0.4634	0.2174	2.132	Cd-Acute-63	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (1,130 mg), *Oncorhynchus mykiss*	0.3528	0.2237	1.577	Cd-Acute-64	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (299 mg), *Oncorhynchus mykiss*	1.210	0.3198	3.784	Cd-Acute-65	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Rainbow trout (289 mg), *Oncorhynchus mykiss*	2.548	1.042	2.445	Cd-Acute-66	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Brown trout (fingerling, 22.4 g), *Salmo trutta*	2.732	0.9770	2.797	Cd-Acute-76	Stubblefield 1990	2.797	2.797
Salmoniformes	Salmonidae	Bull trout (0.200 g), *Salvelinus confluentus*	0.9828	0.4530	2.169	Cd-Acute-79	Stratus Consulting 1999	2.402	2.402
Salmoniformes	Salmonidae	Bull trout (0.221 g), *Salvelinus confluentus*	0.9994	0.3656	2.734	Cd-Acute-80	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0842 g), *Salvelinus confluentus*	3.200	1.254	2.552	Cd-Acute-82	Stratus Consulting 1999		
Salmoniformes	Salmonidae	Bull trout (0.0727 g), *Salvelinus confluentus*	5.942	2.700	2.201	Cd-Acute-83	Stratus Consulting 1999		

Order	Family	Species	LC_{50} (µg/L)	LC_{05} (µg/L)	LC_{50}: LC_{05}	C-R Curve Label	Reference	Species-level TAF (LC_{50}:LC_{05})	Genus-level TAF (LC_{50}:LC_{05})
Cypriniformes	Cyprinidae	Red shiner (adult, 0.80-2.0 g), *Cyprinella lutrensis*	6,731	4,903	1.373	Cd-Acute-85	Carrier 1987; Carrier and Beitinger 1988a	1.373	1.373
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	15,631	8,012	1.951	Cd-Acute-86	Vergauwen 2012; Vergauwen et al. 2013	1.710	1.710
Cypriniformes	Cyprinidae	Zebrafish (adult), *Danio rerio*	12,384	8,263	1.499	Cd-Acute-87	Vergauwen 2012; Vergauwen et al. 2013		
Anura	Pipidae	African clawed frog, *Xenopus laevis*	3,314	1,447	2.290	Cd-Acute-101	Sunderman et al. 1991	2.290	2.290

3.1.1.3 Calculating Sturgeon Acute Cadmium Minimum Effect Threshold
Dividing the white sturgeon LC_{50} value (23.14 µg/L; genus-level surrogate value for shortnose and Atlantic sturgeon) by the acute MAF (2.310) results in an acute cadmium minimum effect threshold concentration of 10.02 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$) for both sturgeon species.

3.1.1.4 Sturgeon: Acute Cadmium Effects Determination
The acute cadmium CMC at hardness of 100 mg/L as $CaCO_3$ (1.9 µg/L total Cd), is over five times lower than the sturgeon acute cadmium minimum effect threshold of 10.02 µg/L total cadmium. The sturgeon acute minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. As a result, refined assessment and consideration of the criterion duration is not necessary and approval of the freshwater acute cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the shortnose and Atlantic sturgeons through direct acute effects.

3.1.2 Sturgeon Chronic Cadmium Effects Assessment: Freshwater

3.1.2.1 Identifying Sturgeon Chronic Cadmium Data
High-quality empirical chronic toxicity data within the Order Acipenseriformes are not available to serve as chronic toxicity data representative of the shortnose and Atlantic sturgeon. As a result, the *Acipenser* GMAV (23.14 µg/L; Table 3-1) was transformed to represent a chronic toxicity value (i.e., EC_{20}) of 2.79 µg/L (Table 3-3). This representative chronic value for the two sturgeon was calculated by dividing the acute toxicity value for white sturgeon (23.14 µg/L; representative of shortnose and Atlantic sturgeon) by the Final Acute-to-Chronic Ratio (FACR) reported in the cadmium criteria document (USEPA 2016). Unlike the ammonia effects assessment that relied on an ACR calculated (geometric mean) from all available vertebrate ACRs, the FACR was used here because ACRs reported in USEPA (2016) vary by more than a factor of ten, even when only considering ACRs from vertebrate species. Additionally, USEPA (2016), states *"... none of the four methods suggested in the 1985 Guidelines (Stephan et al. 1985) for calculating the FACR are appropriate for cadmium... Thus, an alternate approach was used to determine the FACR. The recommended FACR of 8.291 was obtained from the geometric mean of seven genus-level ACRs... Americamysis (7.070), Ceriodaphnia (19.84), Daphnia (23.90), Cottus (11.22), Oncorhynchus (2.0), Salmo (2.0) and Pimephales (17.90).*" The FACR is intended to broadly relate a species acute effect concentration to an estimated chronic effect concentration (EC_{20}).

Table 3-3. Data used to calculate the GMCV representative of sturgeon sensitivity to cadmium.

Order	Family	Species	SMAV (µg/L)[a]	GMAV (µg/L)[a]	FACR	GMCV (µg/L)[a]
Acipenseriformes	Acipenseridae	White sturgeon, *Acipenser transmontanus*	23.14	23.14	8.291	2.79
Acipenseriformes	Acipenseridae	Shortnose sturgeon, *Acipenser brevirostrum*	N/A			
Acipenseriformes	Acipenseridae	Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*	N/A			

[a] Normalized to a hardness of 100 mg/L as $CaCO_3$ (USEPA 2016).
N/A: not available

3.1.2.2 Deriving EC_{20} to EC_5 Chronic Adjustment Factor

High-quality chronic toxicity data were not available for the shortnose and Atlantic sturgeon or surrogate species within the Order Acipenseriformes, and therefore, no raw toxicity data are available to support the derivation of a sturgeon-specific EC_{20}:EC_5 adjustment factor at or below the order-level. As a result, EPA obtained and analyzed raw C-R data for all tests used to derive the chronic criterion (USEPA 2016 Appendix C underlined values) where such data were reported or could be obtained to derive a chronic vertebrate TAF or chronic MAF, if necessary (i.e., if the vertebrate and invertebrate-level chronic TAFs differ from one another).

Raw chronic toxicity data were fit to C-R models using EPA's TRAP software to calculate EC_{20} and corresponding EC_5 values for 40 tests representing 17 species (8 invertebrate and 9 fish species). C-R models were excluded from TAF and MAF calculation if 1) models did not exhibit a unique solution and were flagged by TRAP as having inadequate partial effects; 2) models did not include observations in the region of interest which did not allow TRAP to accurately model a no-response plateau and; 3) models exhibited incongruities such as no or poor fit to key points or excessive noise in the C-R relationship. After exclusion of unacceptable or uncertain EC_{20}:EC_5 ratios, 13 ratios remained resulting in three genus-level EC_{20}:EC_5 ratios for invertebrate species (arithmetic mean = 1.779 µg/L, variance = 0.07706 µg/L) and four genus-level EC_{20}:EC_5 ratios for vertebrate species (arithmetic mean = 1.332 µg/L, variance = 0.008872 µg/L). Analysis of the two means via a two-sample t-test assuming unequal variances ($\alpha = 0.05$) indicated that the means are the same (*t stat [2.677] < t critical for two tail [4.303]*). As a result, the chronic MAF was used to transform the GMCV applicable to the shortnose and Atlantic sturgeon (<4.074 µg/L) to a chronic minimum effect threshold concentration.

Table 3-4 provides the seven genus-level EC_{20}:EC_5 ratios used to derive the chronic MAF. Individual test ratios ranged from 1.229 to 2.097. The chronic MAF calculated as the geometric mean of all genus-level EC_{20}:EC_5 ratios is 1.502 (see Appendix B.3 for raw toxicity test data, TRAP models and outputs for the 13 chronic cadmium toxicity tests used to derive the chronic MAF; Appendix B.4 includes the raw toxicity data, TRAP models and outputs for all unacceptable and uncertain cadmium toxicity tests).

Table 3-4. Chronic EC_{20}:EC_5 ratios from analysis of 13 high-quality chronic cadmium toxicity tests with freshwater aquatic organisms used to derive a chronic cadmium MAF representative of the shortnose and Atlantic sturgeon.

Order	Family	Species	EC_{20} (µg/L)	EC_{05} (µg/L)	EC_{20}: EC_{05}	C-R Curve Label	Reference	Species-level TAF (EC_{20}:EC_{05})	Genus-level TAF (EC_{20}:EC_{05})
N/A[a]	Aeolosomatidae	Oligochaete, *Aeolosoma headleyi*	57.35	27.35	2.097	Cd-Chronic-1	Niederlehner et al. 1984	2.097	2.097
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	4.940	3.352	1.474	Cd-Chronic-12	Southwest Texas State University 2000	1.584	1.584
Diplostraca	Daphniidae	Cladoceran, *Ceriodaphnia dubia*	5.505	3.235	1.702	Cd-Chronic-13	Southwest Texas State University 2000		
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	0.2118	0.1059	2.000	Cd-Chronic-15	Chapman et al. Manuscript	1.657	1.657
Diplostraca	Daphniidae	Cladoceran, *Daphnia magna*	6.166	4.489	1.374	Cd-Chronic-17	Bodar et al. 1988b		
Salmoniformes	Salmonidae	Rio Grande cutthroat trout *Oncorhynchus clarkii virginalis*	2.354	1.659	1.419	Cd-Chronic-24	Brinkman 2012	1.419	1.365
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	2.283	1.774	1.287	Cd-Chronic-26	Davies et al. 1993	1.312	
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.956	3.719	1.333	Cd-Chronic-27	Davies et al. 1993		
Salmoniformes	Salmonidae	Rainbow trout, *Oncorhynchus mykiss*	4.315	3.272	1.319	Cd-Chronic-28	Davies et al. 1993		
Salmoniformes	Salmonidae	Brown trout, *Salmo trutta*	5.187	4.221	1.229	Cd-Chronic-42	Brinkman and Hansen 2004a; 2007	1.229	1.229
Cyprinodontiformes	Cyprinodontidae	Flagfish, *Jordanella floridae*	5.018	3.470	1.446	Cd-Chronic-48	Spehar 1976	1.446	1.446
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.762	1.329	1.326	Cd-Chronic-52	Besser et al. 2007	1.289	1.289
Scorpaeniformes	Cottidae	Mottled sculpin, *Cottus bairdii*	1.285	1.026	1.252	Cd-Chronic-53	Besser et al. 2007		

[a] N/A; not available, no order listed in the Integrated Taxonomic Information System (www.itis.gov) for the species.

3.1.2.3 Calculating Sturgeon Chronic Cadmium Minimum Effect Threshold

Dividing the estimated sturgeon EC_{20} value (2.79 µg/L) by the chronic MAF (1.502) results in chronic minimum effect threshold concentration of 1.86 µg/L (normalized to a hardness of 100 mg/L as $CaCO_3$) for both sturgeon species.

3.1.2.4 Sturgeon: Chronic Cadmium Effects Determination

The cadmium CCC of 0.79 µg/L total Cd (at a hardness of 100 mg/L as $CaCO_3$), is 2.3 times lower than the sturgeon chronic cadmium minimum effect threshold concentration of 1.86 µg/L total cadmium, suggest sturgeon are tolerant to chronic cadmium exposures.

The threshold concentration is based on an acute value calculated from a relatively uncertain C-R curve (e.g., lowest test concentrations [excluding control groups] resulted in 70% mortality; see Cd-Acute-93 in Appendix B.2; see section 3.1.1.1). When deriving criteria and developing effects assessments, EPA relies on the most relevant and high-quality data possible to inform scientifically-sound conclusions. In certain cases, however, EPA may consider lower-quality toxicity data as supportive auxiliary information. Appendix H of the Cadmium 304(a) Aquatic Life Criteria document (USEPA 2016) contains "Other Toxicity Data" for freshwater species and consists of studies that do not meet the rigorous data quality, type, and documentation requirements specified in the 1985 Guidelines (Stephen et al. 1985), yet may contain quality portions that may be considered as supportive auxiliary data.

Appendix H of USEPA (2016) contains four white sturgeon (genus-level surrogate for shortnose and Atlantic sturgeons) chronic toxicity assays obtained from two different publications (Vardy et al. 2011; Wang et al. 2014a). Data from Vardy et al. (2011) are not further considered here because the two chronic toxicity assays reported by Vardy et al. (2011) did not include negative control groups, representing a critical flaw in the underlying study design. Chronic toxicity data for the white sturgeon reported by Wang et al. (2014a) did not contain critical flaws in the study design but were excluded from criteria derivation because reported exposure durations were either too short (EC_{20} < 11 µg/L; hardness = 100 mg/L; endpoint = survival) or were started too late in the sturgeon life stage to constitute an appropriate early life stage test (ELS test; EC_{20} = 3.2 µg/L; hardness = 100 mg/L; endpoint = biomass). Calfee et al. (2014), EPA (2016), and Ingersoll and Mebane (2014) report sturgeon sensitivity to acute cadmium exposures generally increases with increasing days post hatch (up until sturgeon reach a certain age around 72 dph), suggesting it may be appropriate to further consider the EC_{20} (3.2 µg/L) that was excluded from criteria derivation because exposures were started to late to constitute an ELS test. Therefore, EPA divided the EC_{20} value of 3.2 µg/L (Wang et al. 2014a) by the chronic MAF (chronic MAF = 1.502; see Section 3.1.2.2) to calculate a secondary chronic low effect threshold of 2.13 µg/L (hardness = 100 mg/L). The secondary chronic low effect threshold of 2.13 µg/L is similar to the primary chronic low effect threshold of 1.86 µg/L and provides an additional line of evidence to support that sturgeon are tolerant to cadmium at the chronic criterion magnitude (CCC = 0.79 µg/L; hardness = 100 mg/L).

The sturgeon chronic minimum effect threshold concentration, based on continuous laboratory exposures, is greater than the corresponding criterion magnitude. Furthermore, supportive data from less-certain chronic toxicity studies were used to calculate a secondary chronic low effect threshold that is also greater than the corresponding criterion magnitude, providing an additional line of evidence to suggest sturgeon are relatively tolerant to chronic cadmium exposures. As a result, refined assessment and consideration of the criterion duration is not necessary, and approval of the freshwater chronic cadmium water quality standard is Not Likely to Adversely Affect (NLAA) the shortnose and Atlantic sturgeons through direct chronic effects.

3.1.3 Sturgeon Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Acceptable acute saltwater toxicity data for cadmium criteria derivation were available for 94 different estuarine/marine species representing 79 genera, while only two chronic studies conducted on mysid species were available for consideration in deriving the chronic criterion for cadmium in estuarine/marine water. Therefore, the acute estuarine/marine cadmium final acute value (FAV) was transformed by a FACR to derive the chronic criterion magnitude for cadmium in estuarine/marine waters. The four most sensitive genera to acute cadmium exposures were all invertebrates, suggesting vertebrate species, including sturgeon, are relatively insensitive to cadmium toxicity in estuarine/marine waters.

Empirical acute and chronic toxicity data for saltwater life stages of shortnose and Atlantic and sturgeons, or appropriate surrogate species (i.e., members of the Order Acipenseriformes), are not available. Freshwater data, however, suggest sturgeon are most sensitive to cadmium exposures as young fry in freshwaters, and quickly becoming relatively insensitive as they age and migrate toward estuarine and marine waters. USEPA (2016) states, "*Several life stages of the white sturgeon, Acipenser transmontanus, were exposed in flow-through measured exposures by Calfee et al. (2014) and Wang et al. (2014a). The most sensitive life stage were the 61 day post hatch fish with a non-definitive normalized acute value of <33.78 µg/L total cadmium. However, all other life stages were much less sensitive...*" Calfee et al. (2014) reported normalized (hardness = 100 mg/L) white sturgeon LC_{50} values increasing from <33.78 µg/L at 61 days post hatch (dph) to >150.9 µg/L total cadmium at 72 dph, with white sturgeon becoming increasingly tolerant to cadmium at 89 dph with an LC_{50} exceeding 278.6 µg/L. Therefore, Atlantic and shortnose sturgeon life stages occurring in estuarine and marine environments are expected to be relatively insensitive to cadmium.

Because estuarine/marine acute and chronic cadmium criteria are based the fifth centile of sensitive genera (i.e., invertebrates) and designed to protect sensitive genera, the criteria will also protect less sensitive taxa, including sturgeon. Approval of the acute and chronic cadmium estuarine/marine water quality criteria is Not Likely to Adversely Affect (NLAA) shortnose or Atlantic sturgeons through direct effects because only relatively-tolerant sturgeon life stages are expected to inhabit estuarine/marine waters where estuarine/marine criteria are applicable and toxicity data indicate vertebrates are relatively insensitive to cadmium exposures in estuarine/marine waters.

3.1.4 Sturgeon Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

Aquatic life criteria are based on the fifth centile of sensitive genera to protect aquatic communities, including listed species and their prey items. Further, aquatic life criteria are conservatively implemented in National Pollution Discharge Elimination System (NPDES) permit limits by assuming receiving streams are continually at low-flow conditions which significantly limits the probability of *in situ* pollutant concentrations reaching criteria magnitudes and durations. NPDES permit limits based on the acute cadmium criterion typically assume a receiving stream is continually at 1Q10 low-flow conditions, while the probability of these low-flow conditions occurring is exceedingly rare (i.e., 1-day average lowest flow over the course of a 10-year period). Similarly, NPDES permit limits based on the chronic cadmium criterion typically assume receiving streams are continually at 7Q10 low-flow conditions (i.e., 7-day average lowest flow over the course of a 10-year period). As a result, excess dilution limits instream cadmium concentrations and drastically decreases the probability *in situ* cadmium concentrations will reach criteria magnitudes and durations. Independent of assuming low flow conditions, NPDES permits also layer on an additional level of conservatism by ensuring facilities discharge cadmium at Long Term Average concentrations (LTAs), which are based on Waste Load Allocations[2] (WLAs) set as the 99^{th} centile of a log-normal distribution that describes effluent variability. Setting WLAs as the 99^{th} centile of an effluent distribution ensures a 99% chance facilitates discharge cadmium at concentrations less than those that would cause receiving stream cadmium concentrations to reach criteria magnitudes under critical flow conditions (which are independent and also exceedingly rare events; USEPA 1991). Additionally, even if *in situ* exposures were to match the acute or chronic criteria magnitudes, the broad aquatic community, including sturgeon prey items, will be adequately protected because aquatic life criteria are based on the fifth centile of sensitive genera.

Atlantic and shortnose sturgeon broadly rely on benthic invertebrates, including mussels, crustaceans, and insects as primary food sources, all of which are relatively insensitive to acute and chronic cadmium exposures in freshwaters. For example, the most sensitive genera to acute cadmium exposures includes salmonids (*Oncorhynchus*, *Salvelinus* and *Salmo*), sculpin (*Cottus*), and striped bass (*Morone*; Table 7 of USEPA 2016), with pelagic crustaceans (*Hyalella* and *Ceriodaphnia*), sculpin (*Cottus*), and a midge (*Chironomu*s) comprising the four most-sensitive genera to chronic exposures in freshwater (Table 9 of USEPA 2016). In estuarine/marine water, the most sensitive species to acute cadmium exposures (and by extension, chronic cadmium exposure given limited chronic estuarine/marine data) include two mysid genera (*Neomysis* and *Americamysis*), a copepod (*Tigriopus*), and a jellyfish (*Aurelia*). Remaining acute estuarine/marine cadmium toxicity data indicate primary sturgeon prey items, including gastropods, bivalves, oligochaetes, and benthic crustaceans, are also insensitive to acute and chronic cadmium exposures in marine/estuarine environments (Table 10 of USEPA 2016). Even if certain components of shortnose and Atlantic sturgeon diets were among the most-sensitive genera, the sturgeon would not experience any appreciable indirect effects because they are broad opportunistic feeders. Sturgeon consume a wide range of inveterate taxa, which are adequately protected by the cadmium criteria, considering criteria are typically based on the fifth centile of sensitive genera and implemented under conservative exposure conditions.

EPA approval of the freshwater (acute and chronic) and estuarine/marine cadmium criteria (acute and chronic) as Virginia water quality standards is Not Likely to Adversely Affect (NLAA) Atlantic and shortnose sturgeon through indirect effects because: 1) criteria are implemented conservatively; 2) sturgeon prey items are relatively insensitive to cadmium compared to those genera that drive the criteria magnitudes; and 3) sturgeon are not specialized feeders relying on a specific prey item that may be affected by cadmium exposures.

3.2 Sea Turtles: Green (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricate*), Kemp's Ridley (*Lepidochelys kempii*), and Loggerhead (*Caretta caretta*)

3.2.1 Sea Turtle Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Sea turtles are expected to experience no effects associated with approval to the freshwater acute and chronic cadmium criteria due to no co-occurrence of sea turtles and cadmium in Virginia freshwaters. Given the immense dilution associated with marine environments, co-occurrence of sea turtles and cadmium at exposure concentrations and durations associated with the acute and chronic estuarine/marine criteria is also unlikely. For example, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) for estuarine/marine waters in Oregon and concluded:

> "*the proposed action is not likely to adversely affect (NLAA)… loggerhead sea turtles, green sea turtles, leatherback sea turtles, or Olive Ridley sea turtles. The above identified marine…sea turtle species are distributed in coastal areas and may be exposed to effects related to the proposed numeric criteria. Similar to Southern Resident killer whales, effects would be indirect and would include reduced prey availability, reduced prey quality, and potential accumulation in the individuals exposed. However, the occurrence of the subject ESA-listed sea turtles and large whales would be rare, infrequent, and transitory in the action area*."

Moreover, juveniles of all turtle species occurring within Virginia waters forage and mature for several years after hatching in open ocean habitats far from shore (see section 3.2.2), limiting exposure to early life stages, which tend to be the most-sensitive life stage of many taxa to pollutant exposures. Listed sea turtles in estuarine/marine waters of Virginia are not expected to be exposed to cadmium at criteria magnitudes and durations, especially as early life stages. As a result, approval of the acute and chronic estuarine/marine cadmium criteria is Not Likely to Adversely Affect (NLAA) the green sea turtle, leatherback turtle, hawksbill turtle, Kemp's ridley turtle, and loggerhead turtle through direct acute and chronic effects.

3.2.2 Sea Turtle Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

Broadly, all listed sea turtles occurring within the action area share fundamentally similar life cycles and diets. After hatching, green sea turtles swim to offshore areas where they reside for several years feeding close to the surface on a variety of pelagic plants and animals. As adults, green sea turtles travel to foraging grounds closer to shore, feeding primarily on algae and grasses in benthic habitats. As adults they are almost exclusively herbivorous, primarily consuming seagrasses and algae. Leatherback turtles spend the majority of their life in open ocean, except when females must migrate to near shore habitat to lay eggs on sandy, tropical beaches. After nesting season, leatherbacks migrate from tropical waters to more temperate latitudes, which support high densities of jellyfish prey in the summer. Juvenile hawkshill turtles are initially pelagic- sheltering on floating mats of algae and foraging on the surface. As adults, they enter coastal foraging areas near reefs where they feed primarily on algae, sponges, and other invertebrates associated with coral reef environments (NOAA 2017).

After hatching, Kemp's ridley turtles enter water and swim quickly from near shore to escape predators, remaining in open ocean for about two years then return to coastal zones as sub-adults and adults where they forage for prey, including crabs, fish, jellyfish, and mollusks, in muddy or sandy bottom substrates. Loggerhead hatchlings move from their nest to the surf and are swept through the surf zone, and continue swimming away from land for up to several days. Post-hatchling loggerheads reside in areas where surface waters converge to form local down-wellings. Post-hatchlings are observed to be low-energy float-and-wait foragers that feed on a wide variety of floating items. As post-hatchlings, loggerheads may linger for months in waters near the nesting beach or become transported by ocean currents within the Gulf of Mexico and North Atlantic. Somewhere between 7-12 years old, oceanic juveniles migrate back to nearshore coastal areas, foraging on clams, whelks and conch (NOAA 2017).

Listed turtles occurring in Virginia estuarine/marine waters broadly rely on benthic invertebrates, including mussels, crustaceans, and plants as primary food sources, all of which are relatively insensitive to acute and chronic cadmium exposures in freshwaters. In estuarine/marine water, the most sensitive species to acute cadmium exposures (and by extension, chronic cadmium exposure given limited chronic estuarine/marine data) include two mysid genera (*Neomysis* and *Americamysis*), a copepod (*Tigriopus*), and a jellyfish (*Aurelia*). Remaining acute estuarine/marine cadmium toxicity data indicate sea turtle prey items, bivalves, plants, crustaceans, and other invertebrates, are insensitive to acute and chronic cadmium exposures in marine/estuarine environments (Table 10 of USEPA 2016).

Jellyfish rank among the most sensitive genera to acute cadmium exposures in estuarine/marine waters and serve as valuable prey for leatherback turtles; however, aquatic life criteria are based on the fifth centile of sensitive genera and are derived to protect aquatic communities, including jellyfish. For example, members of the genus *Aurelia*, and potentially other members of the order Semaeostomeae, may be sensitive to cadmium exposures in estuarine/marine waters relative to other genera, but are not appreciably sensitive relative to the acute estuarine criterion itself because the *Aurelia* GMAV (61.75 µg/L total cadmium) is nearly two times greater than the estuarine CMC of 33.13 µg/L total cadmium. Similarly, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) on leatherback turtle critical habitat in Oregon and concluded:

> "*The PCEs that NMFS identified as essential for the conservation of leatherback sea turtles…(1) A sufficient quantity and quality of their jellyfish prey…Based on the best scientific and commercial data available, as discussed previously, NMFS does not expect that the proposed action would adversely affect the quantity, quality, or availability of any of the constituent elements of critical habitat, or the*

physical, chemical, or biotic phenomena that give the designated area value for the conservation of the species…"

Sea turtle food resources will not be measurably affected by cadmium at criteria magnitudes and durations associated with the acute and chronic estuarine/marine criteria (USEPA 2016). Further, sea turtles are migratory species and generalist feeders, relying on a range of food resources, both within and outside of the action area, which mitigates any resultants effects of limiting a large portion of a single food resource (which is not the expected outcome of the action). As a result, approval of the acute and chronic estuarine/marine cadmium criteria is Not Likely to Adversely Affect (NLAA) the green sea turtle, leatherback turtle, hawksbill turtle, Kemp's ridley turtle, and loggerhead turtle through indirect effects.

3.3 Whales: Finback (*Balaenoptera physalus*) and North Atlantic Right (*Eubalaena glacialis*)

3.3.1 Whale Acute and Chronic Cadmium Effects Assessment: Estuarine/Marine

Whales will experience no effects associated with approval to the freshwater acute and chronic cadmium criteria due to no expected co-occurrence of whales and cadmium in Virginia freshwaters. Given the immense dilution associated with marine environments, co-occurrence of whales and cadmium at exposure concentrations and durations associated with the acute and chronic estuarine/marine criteria is also unlikely. For example, NOAA fisheries (NMFS 2012) previously assessed the protectiveness of earlier, less stringent, cadmium criteria (USEPA 2001; CMC = 40.28 µg/L; CCC = 8.9 µg/L; hardness = 100 mg/L) for estuarine/marine waters in Oregon and concluded:

"*In this opinion NMFS concludes that the proposed action is not likely to adversely affect (NLAA) Steller sea lions, humpback whales, blue whales, fin whales, Sei whales, sperm whales, North Pacific Right whales…The above identified marine mammal and sea turtle species are distributed in coastal areas and may be exposed to effects related to the proposed numeric criteria. Similar to Southern Resident killer whales, effects would be indirect and would include reduced prey availability, reduced prey quality, and potential accumulation in the individuals exposed. However, the occurrence of the subject ESA-listed sea turtles and large whales would be rare, infrequent, and transitory in the action area. For example, the blue whale and Sei whale are likely to have limited exposure to contaminant sources as their migratory patterns are circumglobal with definite seasonal movements to offshore areas outside the likely extent of effects.*"

The finback whale is unlikely to be exposed to cadmium, or other pollutants, at acute or chronic criterion magnitudes (USEPA 2016) because fin whales are primarily found in deep water, rather than near-shore habitat, significantly reducing exposure potential. Similarly, NOAA Fisheries (NOAA 2017) cited the same rationale to concur finback whales are not likely to be adversely affected by three pesticide contaminants, stating:

Direct effects to listed cetaceans from the action are not expected due to dilution of the three a.i.s (i.e., diazanon, chlorpyrifos, or malathion) *in the marine environments (resulting in a very low potential for exposure) and the cetaceans' very large size (very low potential for effects). Additionally, some of the listed cetaceans are found primarily in deep, ocean waters [i.e., Sei whale (Balaenoptera borealis), Bryde's whale (Balaenoptera edemi), blue whale (Balaenoptera musculus), fin whale (Balaenoptera physalus), humpback whale (Megaptera novaeangliae), and sperm whale (Physeter microcephalus (=icrocephalus)], and/or are circumpolar [i.e., the bowhead whale (Balaena mysticetus)]. Species that are found primarily in deep waters or are circumpolar (i.e., found at high latitudes around the earth's Polar Regions) are expected to range far from any potential application sites – further limiting the potential for exposure.*

While the North Atlantic right whale relies on coastal waters more than the fin whale, exposure potential to cadmium remains negligible, especially because the North Atlantic right whale primarily uses Virginia estuarine/marine waters for migration purposes, as they travel between calving grounds south of Cape Fear, NC, to wintering grounds off of the New England coast (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/north-atlantic-right-whale; Accessed 7/12/2018). Given limited exposure potential and relatively large sizes (limiting potential effects), approval of the acute and chronic estuarine/marine cadmium criteria is Not Likely to Adversely Affect (NLAA) the finback whale or North Atlantic right whale through direct acute and chronic effects.

3.3.2 Whale Cadmium Indirect Effects Assessment: Freshwater and Estuarine/Marine

North Atlantic right whales consume zooplankton and copepods, filtering pelagic organisms from the water column through their baleen (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/north-atlantic-right-whale; Accessed 7/12/2018), while finback whales consume krill, herring, sand lance, capelin, and squid (NOAA Fisheries, Species Directory: www.fisheries.noaa.gov/species/fin-whale; Accessed 7/12/2018). Finback whale range is circum-global and the North Atlantic right whale tend to occupy Virginia marine waters only during migration, providing extensive food resources outside of pelagic organisms occurring in near-shore habitats within the action area. Given available food resources outside of near-shore habitats within Virginia and because aquatic life criteria are based on the 5th centile of sensitive genera to ensure aquatic communities, including whale dietary resources, are protected from acute and chronic cadmium exposures, effects of cadmium exposure to whale prey items within Virginia will be negligible and would insignificantly translate to dietary resources as a whole. For example, NOAA Fisheries (NOAA 2017) cited similar considerations to determine the finback and North Atlantic right whales are not likely to be adversely affected through indirect effects by three pesticides contaminants, stating:

For indirect effects (i.e., reductions in whales' prey), due to the effect of dilution in the types of marine environments in which the listed cetaceans are found and distance from potential use sites, risks from the potential loss of marine

> *invertebrate and vertebrate prey are not expected. Therefore, for the listed cetaceans that rely wholly on marine prey [i.e., …fin*(back) *whale, North Atlantic right whale…), we do not expect indirect effects from the potential loss of prey. For these species, we consider the risk for indirect effects to be low (due to limited exposure) and we have high confidence in this risk assessment.*

Given minimal anticipated effects to whale prey items within and outside of the action area, approval of the acute and chronic estuarine/marine cadmium criteria is Not Likely to Adversely Affect (NLAA) the finback whale or North Atlantic right whale through indirect effects.

4 Conclusion: Final Effects Determinations

Listed sturgeon, turtles, and whales occurring in Virginia freshwaters and/or estuarine/marine waters are insensitive to acute and chronic freshwater ammonia and cadmium exposures at the respective criteria magnitudes under conservative exposure conditions. Further, aquatic life criteria are implemented conservatively and are based on the fifth centile of sensitive genera to ensure aquatic communities, including listed species prey items, are adequately protected. As a result, approval of the acute and chronic ammonia (freshwater) and cadmium (freshwater and estuarine/marine) criteria as Virginia state water quality standards is Not Likely to Adversely Affect (NLAA) aquatic listed species through direct and indirect effects (Table 4-1).

Table 4-1. Final effect determinations for aquatic listed species occurring in Virginia that may be affected by the approval action. Final effects determinations for listed species are based on direct and indirect effects.

Species	Final Effects Determination
Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)	***NLAA*** (direct and indirect effects)
Shortnose Sturgeon (*Acipenser brevirostrum*)	***NLAA*** (direct and indirect effects)
Green Sea Turtle (*Chelonia mydas*)	***NLAA*** (direct and indirect effects)
Leatherback Turtle (*Dermochelys coriacea*)	***NLAA*** (direct and indirect effects)
Hawksbill Turtle (*Eretmochelys imbricate*	***NLAA*** (direct and indirect effects)
Kemp's Ridley Turtle (*Lepidochelys kempii*)	***NLAA*** (direct and indirect effects)
Loggerhead Turtle (*Caretta caretta*)	***NLAA*** (direct and indirect effects)
Finback Whale (Balaenoptera physalus)	***NLAA*** (direct and indirect effects)
North Atlantic Right (*Eubalaena glacialis*)	***NLAA*** (direct and indirect effects)

5 Critical Habitat: Effects Assessment and Final Critical Habitat Effects Determinations

5.1 Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) Critical Habitat

Critical habitat for the Atlantic sturgeon Chesapeake Bay distinct population segment was designated in 2012 and encompasses lower reaches of several Virginia Rivers, including the Potomac, Rappahannock, York, Mattaponi, and Pamunkey Rivers (NOAA 2015). Physical and biological features (PBFs) for "reproduction and recruitment" include (NOAA 2015):

> *Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0-0.5 parts per thousand range) for settlement of fertilized eggs, refuge, growth, and development of early life stages; Aquatic habitat with a gradual downstream salinity gradient of 0.5-30 parts per thousand and soft substrate (e.g., sand, mud) downstream of spawning sites for juvenile foraging and physiological development; Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: (1) unimpeded movements of adults to and from spawning sites; (2) seasonal and physiologically-dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and; (3) staging, resting, or holding of subadults or spawning condition adults. Water depths in the main river channels must also be deep enough (e.g., ≥1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river, and; Water, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: (1) spawning; (2) annual and inter-annual adult, subadult, larval, and juvenile survival; and (3) larval, juvenile, and subadult growth, development, and recruitment (e.g., 13° C to 26° C for spawning habitat and no more than 30° C for juvenile rearing habitat, and 6 mg/L dissolved oxygen for juvenile rearing habitat).*

Approval of the acute and chronic ammonia (freshwaters only) and cadmium criteria (freshwater and estuarine/marine waters) will have no direct effect on any Atlantic sturgeon PBFs reported by NOAA (2015) and is expected to ensure pollutant concentrations are limited to aid in ensuring adequate quality water quality considerations beyond, "*temperature, salinity, and oxygen*." In addition to PBFs, NOAA (2015) also states, "*the ability of subadults to find food is necessary for continued survival, growth, and physiological development to the adult life stage*." Because sturgeon food resources are insensitive to ammonia (see section 2.1.3) and cadmium (see section 3.1.4) at exposure magnitudes and durations specific by the criteria (USEPA 2013 and USEPA 2016, respectively), approval of the ammonia and cadmium criteria will protect from Atlantic sturgeon prey items from harmful ammonia and cadmium exposures. Approval of the acute and chronic ammonia (freshwaters only) and cadmium criteria (freshwater and estuarine/marine waters) will not adversely modify Atlantic sturgeon critical habitat and will aid in the conservation role of critical habitat

6 Conclusion

EPA views the ammonia and cadmium criteria revisions as beneficial to the conservation and protection of aquatic life, including listed species and their food sources in Virginia. EPA recognizes the need to revise its decision if this consultation identifies situations where the criteria may not be adequately protective of listed species populations. If this should be the case, EPA will coordinate with NMFS to determine a reasonable approach.

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[3] To facilitate comparison to the same references cited in EPA's aquatic life criteria documents for Ammonia (USEPA 2013) and Cadmium (USEPA 2016), the subscript lettering for select references in this document is the same as originally cited in the corresponding aquatic life criteria documents (e.g., Wang et al. 2014a in USEPA 2016).

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Attachment 1

Species Listed Under the Endangered Species Act Under the Jurisdiction of NMFS' Greater Atlantic Region (MAINE through VIRGINIA). https://www.greateratlantic.fisheries.noaa.gov/protected/section7/listing/gar_sp_present_table_mar172016.pdf. Accessed on 8/2/18.

SPECIES LISTED UNDER THE ENDANGERED SPECIES ACT UNDER THE JURISDICTION OF NMFS's GREATER ATLANTIC REGION (MAINE - VIRGINIA)

For a list of Candidate Species in the Greater Atlantic Region (GAR), please visit https://www.greateratlantic.fisheries.noaa.gov/protected/pcp/cs/index.html
For a list of Species of Concern in the GAR, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/pcp/soc/index.html

FISH

Atlantic Salmon (*Salmo salar*) (Gulf of Maine DPS)

Year listed: 2000; More recent listing for Gulf of Maine Atlantic salmon as a Distinct Population Segment (DPS) encompassing a wider range in the state of Maine in 2009; Atlantic salmon are listed jointly with U.S. Fish and Wildlife Service.

Status: Endangered

General distribution: The distribution of endangered Atlantic salmon extends from the Androscoggin River in South Western Maine to the Dennys River in Eastern Maine.

Critical habitat in GAR: Critical habitat for Atlantic salmon was designated in 2009. Forty-five specific areas containing over 19,000 kilometers of rivers and streams and 799 square kilometers of lakes and ponds were identified as having the physical and biological features essential to the conservation of the species, which may require special management or protections. For more information, please visit the map book at https://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/ **Additional Information**: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/atlsalmon/ and http://www.fisheries.noaa.gov/pr/species/fish/atlantic-salmon.html

Shortnose Sturgeon (*Acipenser brevirostrum*)

Year listed: 1967

Status: Endangered

General distribution: Shortnose sturgeon occur in marine and estuarine habitat, including freshwater reaches of large rivers with access to the sea, which extends from the Minas Basin, Nova Scotia to the St. Johns River, Florida. There have been documented coastal movements between some of the major rivers.

Critical habitat in GAR: None

Additional Information: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/snsturgeon/index.html and http://www.nmfs.noaa.gov/pr/species/fish/shortnose-sturgeon.html

Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)

Year listed: 2012 (Effective April 6, 2012)

Status: Five Distinct Population Segments (DPSs) designated along the U.S. East Coast. The Gulf of Maine population is listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and South Atlantic populations are listed as endangered.

General distribution: Atlantic sturgeon belonging to each of the five DPSs occur in marine and estuarine habitat, including freshwater reaches of large rivers with access to the sea, from Hamilton Inlet, Labrador, Canada to Cape Canaveral, Florida, U.S. The range of all five DPSs overlap.

Critical habitat in the GAR: In select rivers from Maine through Virginia; Please visit: http://sero.nmfs.noaa.gov/protected_resources/sturgeon/documents/critical_habitat_maps.pdf

Additional Information: For additional distribution information, select references, and other relevant information, please visit https://www.greateratlantic.fisheries.noaa.gov/protected/atlsturgeon/index.html and http://www.fisheries.noaa.gov/pr/species/fish/atlantic-sturgeon.html

MARINE MAMMALS

Blue Whale (*Balaenoptera musculus musculus*)

Year listed: 1970

Status: Endangered

General distribution: The distribution of the blue whale in the western North Atlantic generally extends from the Arctic to at least mid-latitude waters. The blue whale is best considered as an occasional visitor in U.S. Atlantic Exclusive Economic Zone (EEZ) waters, which may represent the current southern limit of its feeding range (CETAP 1982; Wenzel et al. 1988). The actual southern limit of the species' range is unknown.

Critical habitat in GAR: None

Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.fisheries.noaa.gov/pr/species/mammals/whales/blue-whale.html and http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2010whbl-wn.pdf

Fin Whale (*Balaenoptera physalus*)

Year listed: 1970

Status: Endangered

General distribution: Fin whales are common in waters of the U. S. Atlantic Exclusive Economic Zone (EEZ), principally from Cape Hatteras northward. Fin whales are migratory, moving seasonally into and out of high-latitude feeding areas, but the overall migration pattern is complex, and specific routes have not been documented. However, acoustic recordings from passive-listening hydrophone arrays indicate that a southward "flow pattern" occurs in the fall from the Labrador-Newfoundland region, past Bermuda, and into the West Indies (Clark 1995).

Critical habitat in GAR: None

Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/finwhale.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_finwhale.pdf

North Atlantic Right Whale (*Eubalaena glacialis*)

Year listed: 1970; Listed as two separate, endangered species in 2008 - the North Pacific right whale (Eubalaena japonica) and North Atlantic right whale (Eubalaena glacialis)

Status: Endangered

General distribution: Population ranges primarily from calving grounds in coastal waters of the southeastern United States to feeding grounds in New England waters and the Canadian Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence.

Critical habitat in GAR: Expanded to include the Gulf of Maine and Georges Bank. Please see: http://www.fisheries.noaa.gov/pr/species/critical%20habitat%20files/ne_narw_ch.pdf **Additional Information:** For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rightwhale_northatlantic.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_rightwhale.pdf

Sei Whale (*Balaenoptera borealis*)

Year listed: 1970

Status: Endangered

General distribution: The range of the Nova Scotia stock includes the continental shelf waters of the northeastern U.S., and extends northeastward to south of Newfoundland. Indications are that, at least during the feeding season, a major portion of the Nova Scotia sei whale stock is centered in northerly waters, perhaps on the Scotian Shelf (Mitchell and Chapman 1977). The southern portion of the species' range during spring and summer includes the northern portions of the U.S. Atlantic Exclusive Economic Zone (EEZ) — the Gulf of Maine and Georges Bank. Spring is the period of greatest abundance in U.S. waters, with sightings concentrated along the eastern margin of Georges Bank and into the Northeast Channel area, and along the southwestern edge of Georges Bank in the area of Hydrographer Canyon (CETAP 1982).

Critical habitat in GAR: None

Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/seiwhale.htm and http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/atlantic/2015/f2015_seiwhale.pdf

Sperm Whale (*Physeter macrocephalus*)

Year listed: 1970

Status: Endangered

General distribution: Sperm whales feed on larger organisms that inhabit the deeper ocean regions (Whitehead 2002). Calving for the species occurs in low latitude waters. The distribution of the sperm whale in the U.S. Exclusive Economic Zone (EEZ) occurs primarily on the continental shelf edge, over the continental slope, and into mid-ocean regions.

C**ritical habitat in GAR:** None

Additional Information: For additional distribution information, select references, and other relevant information, please visit http://www.fisheries.noaa.gov/pr/species/mammals/whales/sperm-whale.html and http://nefsc.noaa.gov/publications/tm/tm231/63_spermwhale_F2014July.pdf

SEA TURTLES

While sea turtles occur year-round off the southeastern United States, they are generally present in marine and estuarine waters of the GAR from April through November. As water temperatures warm in the spring, sea turtles begin to migrate to nearshore waters and up the U.S. Atlantic coast, occurring in Virginia as early as April/May and in the Gulf of Maine in June. The trend is reversed in the fall with some animals remaining in the GAR until late fall. Outside of these times, sea turtle presence in GAR waters is considered unlikely, although juvenile sea turtles routinely strand on GAR beaches during colder months (i.e., from October to January) as a result of cold-stunning. Nesting is extremely limited in the GAR. Typically, juveniles and, to a lesser extent, adults are present in the GAR. Sea turtles are listed jointly with U.S. Fish and Wildlife Service. For additional distribution information, select references, and other relevant information, please visit https://www greateratlantic.fisheries.noaa.gov/protected/seaturtles/index.html and http://www.nmfs.noaa gov/pr/species/turtles/

Green Sea Turtle (*Chelonia mydas*)

Year listed: 1978; Eleven Distinct Population Segments (DPSs) designated in 2016

Status: The Central North Pacific, East Indian-West Pacific, East Pacific, North Atlantic, North Indian, South Atlantic, Southwest Indian, and Southwest Pacific DPSs are listed as threatened. The Central South Pacific, Central West Pacific, and Mediterranean DPSs are listed as endangered. Only the North Atlantic DPS is present in the GAR.

General Distribution: In the U.S. Atlantic, green turtles are occasionally found as far north as New England, but are more commonly seen from New York south. They occur seasonally in GAR waters, including but not limited to the Chesapeake Bay and Long Island Sound, which serve as foraging and developmental habitats.

Critical habitat in GAR: None

Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/green.html

Hawksbill Turtle (*Eretmochelys imbricata*)

Year listed: 1970

Status: Endangered

General Distribution: Hawksbill turtles are circumtropical. In the U.S. Atlantic, they are found primarily in Florida and Texas, though they have been recorded along the east coast as far north as Massachusetts. Hawksbills are rare visitors to the waters of the GAR.

Critical habitat in GAR: None

Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/hawksbill.html

Kemp’s Ridley Turtle (*Lepidochelys kempii*)

Year listed: 1970

Status: Endangered **General Distribution:** Kemp's ridleys typically occur only in the Gulf of Mexico and the northwestern Atlantic. In the U.S. Atlantic, they are found as far north as New England seasonally. Foraging areas in the GAR include, but are not limited to, Chesapeake Bay, Delaware Bay, Cape Cod Bay, and Long Island Sound.

Critical habitat in GAR: None

Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/kempsridley.html

Leatherback Turtle (Dermochelys coriacea)

Year listed: 1970

Status: Endangered

General Distribution: Leatherback sea turtles are globally distributed. They range farther than any other sea turtle species. Although frequently thought of as an oceanic species, they are also known to use coastal waters of the U.S. continental shelf. Juveniles and adults are present in the GAR seasonally and are distributed as far north as Canada.

Critical habitat in GAR: None

Additional Information: http://www.nmfs.noaa.gov/pr/species/turtles/leatherback.html

Loggerhead Turtle (Caretta caretta)

Year listed: 1978; Nine Distinct Population Segments (DPSs) designated in 2011

Status: The Northwest Atlantic, South Atlantic, Southeast Indo-Pacific, and Southwest Indian Ocean DPSs are listed as threatened. The Northeast Atlantic, Mediterranean, North Indian, North Pacific, and South Pacific Ocean DPSs are listed as endangered. Only the Northwest Atlantic DPS is present in the GAR.

General Distribution: Loggerheads, the most abundant species of sea turtle in U.S. waters, have a temperate and subtropical distribution, including offshore waters, continental shelves, bays, estuaries, and lagoons. In the U.S. Atlantic, their range extends north to southern Canada. They most commonly occur throughout the inner continental shelf from Florida to Massachusetts. As with other sea turtle species, their presence in the GAR varies seasonally.

Critical habitat in GAR: Sargassum critical habitat in offshore waters associated with the Gulf Stream current off Maryland and Virginia.

Additional Information: http://www.nmfs.noaa gov/pr/species/turtles/loggerhead.html and http://www.nmfs.noaa.gov/pr/species/turtles/criticalhabitat_loggerhead.htm